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Wm. A. Rudell
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UNIVERSITY OF TORONTO

COLLEGE BOTANY,

INCLUDING

ORGANOGRAPHY,
VEGETABLE HISTOLOGY, VEGETABLE PHYSIOLOGY
AND VEGETABLE TAXONOMY.

WITH A BRIEF ACCOUNT OF THE SUCCESSION OF PLANTS IN GEOLOGIC TIME, AND A

Glossary of Botanical Terms.

SECOND REVISION, WITH NEARLY SIX HUNDRED ILLUSTRATIONS, LARGELY FROM DRAWINGS BY THE AUTHOR.

BY

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CHICAGO:
G. P. ENGELHARD & COMPANY.
1890.

J. A. Carveth & Co.
Toronto, Ont.

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To My Wife,

WHOSE COMPANIONSHIP IN MY SCIENTIFIC PURSUITS AND WHOSE SYMPATHY LIGHTEN THE CARES OF A BUSY LIFE

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PREFACE.

WHEN the first edition of the "Elements of Botany" was exhausted and a revision became necessary, it was deemed best to supply its place with two books, one especially suited to the use of colleges and of schools of pharmacy and medicine, and the other, a briefer and more elementary work, adapted to the use of high schools and academies.

The new books are, of course, outgrowths of the old one, and some pains have been taken to conserve all those features which caused the latter to be so favorably received by teachers. In the "College Botany," as well as in the "Elements," the need of avoiding unnecessary technicalities, and of producing a book which any student of fair intelligence may pursue with interest and profit without the aid of a teacher, has been steadily kept in mind. If the author has succeeded in this aim, the book, he believes, will not, on that account, be any the less useful in the work of the class-room.

As was stated in the preface to the previous edition, it has seemed to the author that many of the text-books on botany were made unnecessarily difficult for students, and that for this cause they are often repelled from a subject which ought to be one of the most interesting in the whole range of science. For this reason the common, as well as the scientific, names of plants have been given, and, so far as possible, familiar plants have been selected for the illustration of structures.

While, it is believed, the book covers all the ground that is desirable in a college course, it must be understood that it is not written for specialists, but rather to smooth the way for the many to the delightful study of plants, to acquaint them with some of the more important facts of the science, and to initiate them into the most approved methods of study.

The order of treatment is also substantially the same as that in the former edition, in which it was said "That order is not always best for the average student that is best for the well disciplined mind. The logical arrangement of a mass of scientific facts is not, necessarily, the logical order of inculcating them. * * * In preparing this text-book, an effort has been made to * * * present the elementary facts and principles of the subject simply, clearly and with regard to the natural order of growth of the mental faculties of the student." The aim has been to lead him from that which is familiar to that which is less so—from the known to the unknown. He is, therefore, first taught to observe the various organs of the higher plants—roots, stems, leaves, etc.,—without other aids than good eyes, deft fingers, a pocket-knife and a magnifying lens, before he is introduced to the intricacies of cell-structure, a good understanding of which requires the skillful use of the compound microscope.

For this work, very considerable portions of Parts I, II and III, of the "Elements," have been rewritten, and much new matter added ; and Part IV has been wholly rewritten and much extended. To the chapters on Organography and Vegetable Histology some additional practical exercises have been appended, and a series of them have now, for the first time, been appended to the chapters on Vegetable Physiology. The appendix to Part II, relating to the microscope and the mode of using it in Vegetable Histology, has received many important additions with the view of making the volume a complete laboratory guide. In Part IV, important changes have been made in the classification. The attempt to arrange plants strictly in accordance with their modes of reproduction, has been abandoned, both as impracticable in the present state of our knowledge, and as inconvenient in use, and the Algæ, Fungi and Lichenes are restored to their old rank as separate classes. Some other changes of less importance are made in the minor groups, and to this Part is appended a brief account of the succession of plants in geologic time.

The Glossary of Botanical Terms has also been revised and extended. Nearly all the old illustrations made use of in the present edition have been re-engraved, and many new ones have been added, some of these from drawings by the author, others from various standard works. These changes have, of course, necessitated a resetting of all the type.

The credit of the wood-engraving is due to Mr. Chase Thorne, of Chicago.

To the friendly aid of many botanists who, by advice and kindly criticism of the former work, have greatly assisted in the preparation of this one, the author acknowledges a deep sense of gratitude. To Dr. Thomas J. Burrill, of the Illinois University, he feels particularly thankful for kindly suggestions.

Among the works consulted in the preparation of this revision, are Gray's Structural Botany, Sachs' Physiology of Plants, Goodale's Physiological Botany, Vines' Physiology of Plants, Bessey's Botany, LeMaout and Decaisne's Descriptive and Analytical Botany, Strasburger and Hillhouse's Practical Botany, Shore's Vegetable Biology, Bower and Vines' Practical Botany, Poulsen's Botanical Micro-Chemistry, Behrens' Guide to the Microscope in Botany, DeBary's Comparative Anatomy of Phanerogams and Ferns, Prantl and Vines' Text Book of Botany, Goebel's Outlines of Classification and Special Morphology, Foster's Physiology, Dawson's Geological History of Plants, and LeConte's Elements of Geology.

EDSON S. BASTIN.

CHICAGO, Jan. 19, 1889.

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A WORD TO THE STUDENT.

Remember that the study of Botany is primarily the study of plants, and not the study of books about plants. If you study the book only, you will almost certainly find it dry and unprofitable; but if you use it as a guide to the study of plants, and study it *plant in hand*, verifying its descriptions by observations of your own, you will find the work not only profitable, but intensely interesting. To guide you in the observation and study of plants, practical exercises are added at the end of each chapter. It is hoped you will give to these a due share of your attention.

At the beginning of your study provide yourself with a suitable simple microscope. If economy is a consideration, you may cheaply obtain a double convex lens of about one inch focus, simply mounted in ebonite or brass, that will answer the purpose well, for it may either be used as a hand magnifier or it may easily be arranged to slide up or down on a piece of steel wire fastened upright in a block of wood, so that both hands may be left free for the dissection of small flowers or other structures, or for the tearing apart of tissues. Make habitual use of the lens during the course of your studies.

BOTANY.

INTRODUCTION.

Botany may be defined as *the science of plants.* It constitutes one of the two grand divisions of organic science, the other being zoology, or the science of animals. In its broadest sense it includes all classified knowledge of vegetable organisms from the lowest to the highest. A science of such scope has, of course, many branches, each of which is of more or less importance. Plants may, for example, be considered with reference to the parts or organs of which they are composed, and the minute structure of these parts, giving rise to the departments of Structural Botany, including Organography and Vegetable Histology: they may be viewed with reference to the modifications, changes and adaptations that different organs undergo, and this will give rise to the science of Vegetable Morphology; they may, again, be regarded with reference to the uses of the various organs—the way they perform their work of vegetation and reproduction—and this view gives rise to Vegetable Physiology: we may consider them with reference to their relations to each other, comparing and classifying them according to resemblances and differences, and this mode of viewing them results in the science of Plant Classification, Vegetable Taxonomy or Systematic Botany; once more, we may study them with reference to their distribution in time and space, and this mode of study gives rise to Paleontological and Geographical Botany respectively; lastly, we may regard them in the light of their economic uses or their relations to human weal, which gives origin to the various branches of economic botany, as Forestry, Floricultural, Agricultural, Horticultural, Pharmaceutical and Medical Botany.

For the purposes of this work the subject will be treated of mainly under four heads, as follows :

I. Organography, that branch of structural botany which treats of the organs or instruments with which plants do their work, as roots, stems, leaves, parts of flowers, etc., their forms and modifications.

II. Vegetable Histology, that branch of structural botany which treats of the minute or microscopical structure of plants.

III. Vegetable Physiology, that branch of botanical science that treats of the functions of plants and their organs ; that undertakes to explain how the plant and its various parts perform their work.

IV. Vegetable Taxonomy. Under this head will be considered the mode of naming and classifying plants, and some brief account of the life histories of the more important types of vegetable life will be given.

Some subjects which cannot be strictly included under any of the above heads will also be briefly treated. Due attention will be given to vegetable morphology in the first two parts, and a brief account of the geological succession of plants will be given in separate chapters at the close of Part IV.

PART I.

ORGANOGRAPHY.

GENERAL CONSIDERATIONS.

The lowest forms of plant life are so simple in their structure that they can hardly be said to possess distinct organs or parts for the performance of different kinds of work. With them, so to speak, the work of vegetable life is performed without implements, in the rudest manner. But as we pass up the scale of vegetable life we find plants growing more and more complex in their structures, the plant body tends more and more to be divided into organs, till at last, when we reach the highest group, the flowering plants, we find it to consist of a variety of parts, each differing from the other in appearance and structure, and each contributing in a somewhat different way to the life of the whole organism. Our study, therefore, of organography will be mainly confined to the organs of the higher plants, where we find them most highly developed.

In flowering plants we observe two kinds of organs; first, *the vegetative*, or those which imbibe, circulate and elaborate food, and contribute to the vegetable life of the plant; and second, the *reproductive*, or those whose function it is to reproduce the species.

The vegetative organs consist of Roots, Stems, Leaves and Hairs. All of these organs occur under numerous modifications. The same plant may bear several different kinds of each of them, some adapted to one use, others, perhaps, to quite a different one, so that what is, morphologically speaking, the same organ, may perform a variety of quite distinct functions. It is not Nature's method to create new organs when new uses are required, but to reshape and modify already existing ones, and fit them for the new requirements. If, for example, it is of advantage to the plant to climb, a leaf or a branch is converted into a tendril, and if the good of the species requires that it be defended against predacious animals, hairs are modified into prickles, or branches or leaves into thorns. Thus it happens that the same organ exists under such various forms and disguises, and the skill of the botanist is nowhere better shown than in his ability to penetrate the character of these disguises and determine what organs have been modified to produce them.

THE ORGANS OF VEGETATION.

Some of the flowerless plants below mosses possess clearly defined plant-hairs, and in rare instances an indistinct differentiation of stem and leaf. In the mosses the distinction becomes sharp and clear, but they do not possess roots. It is not till we reach the Pteridophytes, or highest group of flowerless plants, that we find a complete differentiation of all the vegetative organs. The order of their evolution, therefore, seems to be as follows: First, plant-hairs, or trichomes, then leaf and stem, and lastly roots. In complexity of structure plant-hairs rank lowest and leaves highest, while roots are next to plant-hairs, and stems next to leaves.

CHAPTER I.—THE ROOT.

The root may be defined as *that part of the plant-axis which does not bear leaves.* Roots are ordinarily subterranean in their habits, and serve the double use of attaching the plant securely to the soil and of enabling it to absorb from it the necessary food. These are their normal uses, but they sometimes take upon themselves additional functions. The roots of the Carrot, Beet and Turnip, for example, not only subserve these functions, but also that of storehouses for food. These plants are biennials, and during the first year of their growth they store away in their fleshy roots great quantities of nutrient materials, which, during the succeeding year is expended in the production of flowers and fruits. Many perennial herbs, like the Dahlia, though the above-ground parts perish at the close of every season, are able to survive by means of their under-ground parts, because they store away, year by year, in their tuberous roots, the materials necessary for the succeeding year's growth. The famous Banyan Tree of India sends downward, from its huge horizontally spreading branches, roots which make their way to the soil, and serve not only the ordinary uses but also that of props or subsidiary stems to support the weight of the branches.

But there are many instances of roots whose habits and functions are quite different from the ordinary. The roots of air plants or *epiphytes*, like those of many tropical orchids, for example, never reach the soil at all, but cling to the bark of trees and absorb nutriment from the air; the rootlets that spring out laterally from the stems of the Poison Rhus, Trumpet Creeper and Ivy, Fig. 1, serve purely the use of climbing organs; those of the Mistletoe and Dodder penetrate the bark of the plants on which they find lodgment, and live at the expense of the nutritious juices absorbed from their hosts; a leafless epiphytic orchid belonging to the genus Aeranthus produces roots which perform no proper root-functions at all, but develop in their interior the green coloring-matter of leaves, and do the duty which ordinarily devolves upon leaves.

Roots differ from stems in some important particulars, notably the following: They are much less regular in their mode of branching, they are simpler in their internal structure, they do not directly bear leaves or leaf-rudiments, their growing-point is located just back of the apex instead of at the apex, and in consequence of this sub-apical growth, the tip, unlike that of the stem, becomes

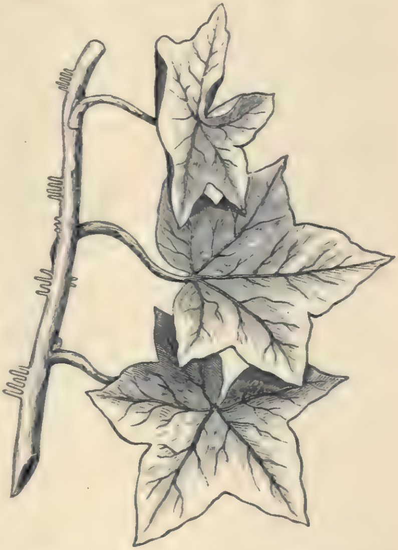


FIG. 1.—Portion of stem of Ivy showing rootlets.

covered with a protecting sheath or cap of older and thicker-walled cells, technically called the *root-cap*, which affords it a decided mechanical advantage in penetrating the soil.

The absorbing surface exposed by roots to the soil is much greater than is usually supposed. In most plants it is probably comparable in extent with that exposed by the leaves to the air. This great superficial area which roots present to the soil is due partly to their repeated ramifications into fine divisions, and partly to the numerous delicate root-hairs that are found on the ultimate branches just back of the growing-point. The finer root-branches, together with their attached hairs, are the chief agents by which the plant absorbs nutriment from the soil, and on them, therefore, more than on the larger roots, is the life of the plant dependent. The principal reason why transplanting in midsummer is so dangerous to the life of the plant, is that in the process of digging up and re-setting, numerous root-tips with their absorbing hairs are broken off and destroyed, so that the leaves evaporate water much faster than it can be taken up by the remaining roots, and the plant, therefore, necessarily withers. Fig. 2 represents a root-tip considerably magnified, showing its growing-point *a*, its root-hairs *b*, and its root-cap *c*.

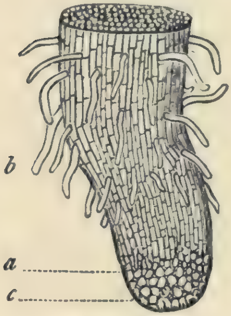


FIG. 2.

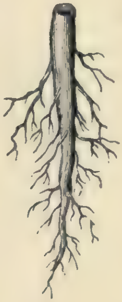


FIG. 3.

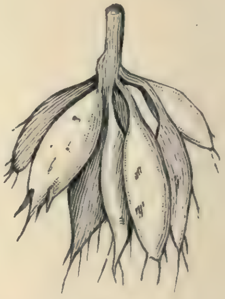


FIG. 4.

FIG. 2.—A root-tip considerably magnified. *a*, the growing point ; *b*, root-hair ; *c*, the root-cap.
FIG. 3.—The tap-root of the common Stock.
FIG. 4.—The clustered and tuberous roots of the Dahlia.

Roots may be classified into *primary* and *adventitious*. A primary root is the downward continuation of the embryonic root of the seed. Commonly it is simple, or the branches it produces are small as compared with the main root; in this case it is called a *tap-root*. Fig. 3 represents the tap-root of the common Stock. Sometimes, however, the embryonic root almost immediately breaks up into numerous similar branches, forming *multiple primary* roots. These may become thickened and *tuberous*, as in the Dahlia, Fig. 4, or they may remain slender and *fibrous*, as in the roots of the Plantain.

Not infrequently the primary root disappears altogether at an early stage of the development of the plant, and is replaced functionally by other roots springing out laterally from the stem higher up. This is almost universally the case with the large group of flowering-plants called Monocotyledons, typified by the Lilies, Palms, Grasses and Sedges, and with the higher flowerless plants, such as Ferns, Club-mosses and Horse-tails. Roots of this character and all others which originate laterally from stems, branches or leaves, whether above ground or beneath it, are called adventitious roots. Such are the aerial roots of the Ivy, illustrated in Fig. 1, the roots which spring from the branches and above-ground stems of various species of the Fig, from the joints of some grasses, and from the rhizomes or underground stems of such plants as Podophyllum, Serpentaria and Iris.

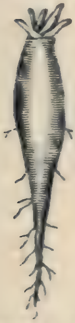


Fig. 5.

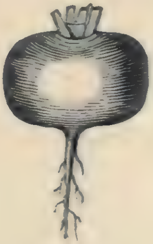


Fig. 6.

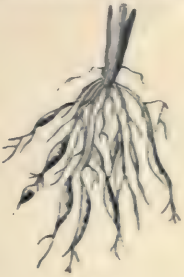


Fig. 7.

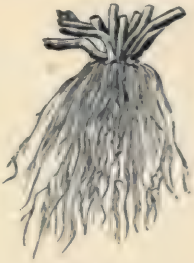


Fig. 8.

Fig. 5.—Fusiform root of the Radish.
Fig. 6.—Napiform root of the Turnip.
Fig. 7.—Nodose roots of the Dropwort.
Fig. 8.—Fibrous roots of a Grass.

It is often convenient to describe roots by their shapes. That of the Carrot, which is thick at the base and tapers gradually to the apex, is called *conical;* one which is shaped like the root of the Radish, Fig. 5, is called *fusiform;* one shaped like that of the Turnip, Fig. 6, *napiform;* roots like those of the Dropwort, Fig. 7, *nodose;* roots like those of the Sweet-potato and Dahlia, Fig. 4, *tuberous;* roots which are wholly slender and thread-like, as those of most grasses, Fig. 8, *fibrous;* and roots which terminate abruptly, as if bitten off, *premose.*

PRACTICAL EXERCISES.

Cause some seeds of common plants, as the Pumpkin, Pea, Corn, etc., to germinate over water so that the roots do not pass into the soil. A convenient way is to fill a wide-mouthed bottle half or two-thirds full of water, and, after fitting a cork to it, fasten by means of wires the seeds to the under surface of the cork, and insert it in the mouth of the bottle, and set the latter away for a few days in a warm place. The seeds will soon germinate, and the forms of their roots, and their structure and habits of growth, may be studied.

Observe and describe the forms and modes of branching of the different roots; by means of the magnifying lens study the root-hairs, observing on what parts of the rootlets they are most abundant; determine whether the roots are primary or secondary in their character, and examine the tips of the roots for the root-cap. Procure specimens of the common Duck-weed, in which the root-cap is highly developed, and examine it with care. As examples of aerial roots, study those of the Ivy, and as examples of the roots of parasites, study those of the common Dodder or of the Mistletoe, making sections of them and of their host-plants in such a way as to observe how the roots penetrate the bark of the host.

Record, in appropriate descriptive language, and by means of drawings, the results of your observations.

CHAPTER II.—THE STEM.

The stem may be described as *that part of the plant-axis which bears leaves or some modification of them.* Its ordinary functions are to form such a support for the leaves as will duly expose them to the influence of the light and air, to bear the floral organs and convey to them the nutriment they require, and to form a means of communication and interchange between the roots, or organs which absorb the crude nutritive materials from the soil, and the leaves, or organs which assimilate these materials. But, like other vegetative organs, they are often modified, as we shall presently see, so as to subserve functions quite different from the normal. Besides bearing roots, leaves and hairs—appendages different from itself—a stem, commonly, though not always, bears branches, or appendages essentially like itself. A stem differs from a root not only in the fact that it is leaf-bearing, but in having its branches, for the most part, arranged with mathematical regularity, and in the fact that the growing-point is strictly apical instead of sub-apical. A stem also increases in length by the growth of a terminal bud, and its branches commonly originate from buds which spring from the angle where the leaf joins the stem. We should first understand the nature of buds.

Buds are in reality rudimentary stems, with rudimentary leaves compactly arranged upon them. In the growing season we observe them constantly unfolding. The short bud-axis which bears the minute closely packed leaf-rudiments is constantly lengthening below, carrying the rapidly expanding leaves farther apart and developing into a leafy branch, while above, the bud is continually being renewed. Such a bud is not covered with scales. Its leaves are all destined to develop into foliage.

On some trees the buds that exist during the season of rest are similar, except as respects the stoppage of their growth, to those of the growing season. Such buds are usually of very small size, and in some cases they are wholly or partially concealed beneath the corky layer of the bark. Buds of this kind are called ***naked buds***.

But most of our northern trees, at the approach of the cold season, form *scaly buds*, which differ from those of the growing season by having the outer leaf-rudiments transformed into scales which never develop into true leaves, but whose sole function is to protect those within, which in the spring are destined to develop either into foliage or into floral organs. Such buds are usually conspicuous, and they often attain a considerable size, as, for example, in the Hickory.

The scales of scaly buds are admirably adapted for protective purposes. They contain but little water, and are therefore bad conductors of heat, thus preventing the occurrence of too sudden changes of temperature in the interior of the bud, and in many instances they have either a lining of downy hairs or are covered with an insoluble varnish, which further increases their non-conductivity at the same time that it prevents the penetration of water. If the water were permitted ingress, by freezing and thawing, it would injure, if not destroy, the delicate organs which the scales enclose.

Fig. 9 represents a twig of the Ohio Buckeye as it appears in the late autumn or early spring. At the apex is a large scaly bud; below, situated in the axils of leaf-scars, are smaller axillary buds. Fig. 10 is a longitudinal section of one of the large terminal buds of the same tree, showing the very short axis and compactly arranged leaf-rudiments.

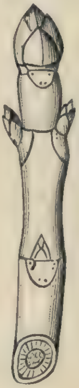


FIG. 9.

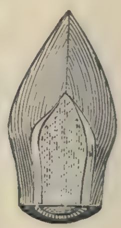


FIG. 10.

FIG. 9.—Portion of twig of Ohio Buckeye, natural size, with terminal and axillary buds, and leaf-scars,

FIG. 10.—Enlarged view of longitudinal section of a terminal bud of the same tree, showing the manner in which the scales overlap.

Buds normally occur as represented in Fig. 9, either at the ends of the stems, when they are called *terminal buds*, or in the axils of leaves, when they are called *axillary buds;* sometimes, however, they occur in other situations on the stem, and occasionally they are found on roots or even on leaves; in all these cases they are termed *adventitious buds.*

Examples of buds of this kind occur occasionally on the American Elm when the surface of the stem has been abraded or irritated, causing an extra supply of nourishment to flow to the spot; the compact bunches of twigs sometimes seen on these trees originate from such buds; the shoots which often arise in great numbers from the trunk of a pollarded willow have a similar origin; the leaves of Bryophyllum, when they have been shed, habitually produce marginal buds that, under favorable conditions, root and form new plants (see Fig. 11), and the occurrence of adventitious buds on the roots of some species of Poplar, causes them habitually to send up shoots at a distance from the main trunk.

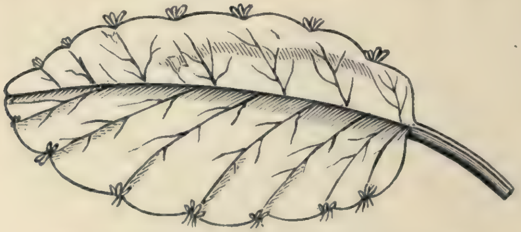


FIG. 11.—Leaf of Bryophyllum, with marginal buds.

It often happens, also, that more than one bud is formed in or near the axil of the leaf; extra buds of this kind are called *accessory* or *supernumerary* buds. Sometimes they are placed side by side as on the Apple-tree and as is most commonly the case, but sometimes one above the other, as on the Butternut and Walnut.

Size of Stems. Stems differ widely in this respect. Some, as those of certain mosses, are scarcely the one twenty-fifth of an inch in length, and the diameter does not exceed that of a fine thread, while those of the giant Sequoia of California, and a species of Eucalyptus in Australia attain the remarkable height of more than four hundred and twenty feet.

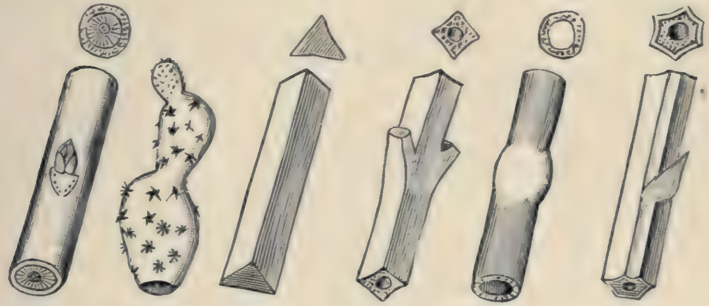


FIG. 12. FIG. 12a. FIG. 13. FIG. 13a. FIG. 14. FIG. 15.

FIG. 12. —Terete or cylindrical stem of Basswood.
FIG. 12a.—Flattened stem of Opuntia Cactus.
FIG. 13. —Triquetrous or triangular stem of a species of Scirpus or Rush.
FIG. 13a.—Quadrangular stem of Mint.
FIG. 14. —Jointed stem of Barley.
FIG. 15. —Fluted stem of Parsnip.

Shapes of Stems. In this respect they differ no less widely. The ordinary or typical form is that of a cylinder, or rather a very much elongated cone; such a stem is described as *cylindrical* or *terete* (see Fig. 12); but sometimes it is flattened as in the stems of some species of Cactus, Fig. 12a; sometimes *triangular* or *triquetrous*, as in some species of the Rush, Fig. 13; sometimes *square* or *quadrangular*, as in many Mints and Scrophularias, Fig. 13a; sometimes *jointed*, as in the stems of the Grasses, Fig. 14; and sometimes *fluted*, as in the stem of Valerian and that of the Parsnip, Fig. 15. In a Palm which is native to the Amazon valley, the Iriartea ventricosa, and in the curious Bottle-tree of Australia, the trunk is strongly bulged or swollen in the middle; in the so-called stemless plants, like the Dandelion, it is short and broad, forming scarcely more than a point or thin disc, from which the roots shoot downward and the leaves upward; and in the Cactuses, succulent Euphorbias and some other families of plants, it assumes a great variety of irregular or oddly grotesque forms.

Direction of Growth. In this respect also there is great diversity. The larger proportion of aerial or above-ground stems are upright or *erect*, but some are *ascending*, that is, they rise obliquely upward; some are *reclining*, or at first erect, but afterwards bending over as if too weak to stand; some are *decumbent*, or creeping along the ground, but with the apex ascending; some are *procumbent* or prostrate, that is, lying wholly upon the ground, and still others are *repent*, or creeping along the ground, rooting as they grow

Duration of Stems. There are wide differences in this respect also. Some attain their full size in a few days, and in a few days more completely disappear, while there are others that possibly endure for a thousand years, and the vegetable world presents almost every gradation between these two extremes.

A stem which dies down to the ground at the close of the season is called *herbaceous;* an herb whose life terminates with the season, or which springs from the seed, blossoms, ripens its fruits, and dies completely all in the same season, is called an *annual;* if, however, the stem dies, but the underground parts retain their vitality, and growth is continued another season, during which the seeds are perfected, and it then dies completely, it is called a *biennial;* and if by underground parts the life of the plant is continued indefinitely, through a period of years, it is called a *perennial.* An aerial stem that is woody, freely branching from near the ground, and of small size, not more than two or three times the height of a man, is called shrubby or *fruticose;* if the stem is of a small size and woody only at the base, it is described as an under-shrub or as *suffruticose;* if the stem is woody with a single trunk, and rises not higher than twenty-five or thirty feet, it is called *arborescent;* and if similar to the last, but of larger size, rising to the height of thirty feet or more, it is termed *arboreous.*

Kinds of Above-ground Stems as Regards Habits of Growth. Among the more important of these are the following :

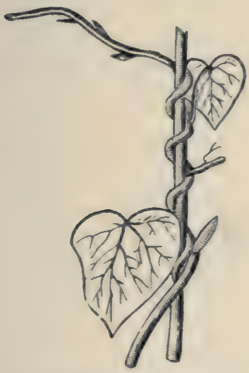


FIG. 16.—Voluble or twining stem of the Morning-glory.

The *twining* or voluble stem is one which twists or coils about a support, as the stem of the Morning-glory, Fig. 16, and that of the Hop.

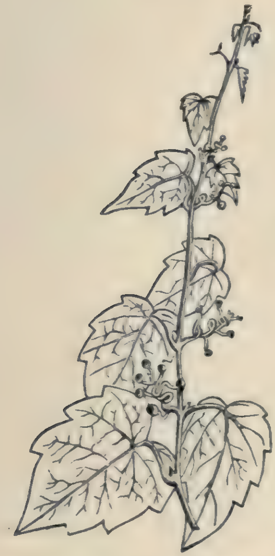


FIG. 17.—Portion of the stem of Ampelopsis Veitchii, showing branching tendril, provided with terminal sucker-like discs.

The *scandent* or climbing stem is one that rises by attaching itself, by means of special organs modified for the purpose, to some extraneous support. There are various modes of climbing. The Tropeolum and Solanum jasminoides, for example, climb by means of sensitive petioles, Fig. 18 ; the Ivy, and Poison Rhus by means of rootlets ; the Grape and Ampelopsis Veitchii, by means of tendrils, Fig. 17, and some species of the Rose and Bramble climb in a rude way by means of hooked prickles. Tendrils also may be either modified branches, as in the Grape ; modified leaflets, as in the Pea, or modified stipules, as in the Sarsaparilla.

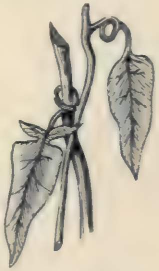


FIG. 18.— Portion of stem of Solanum jasminoides, a leaf-climber.

The *Culm* is the peculiar jointed stem of the Grasses and Sedges. It may be herbaceous, as in Wheat and Rye, or woody, as in the Cane and Bamboo.

The *scape* is a flowering stem destitute of true foliage leaves, as those of the Dodecatheon and Dandelion.

The *Caudex* is such a scaly unbranching stem as we observe in Palms and Tree Ferns.

The *Stolon* is a prostrate or declined branch, the end of which, on coming in contact with the soil, takes root, and ultimately gives rise to a new plant. The Currant and Raspberry afford examples.

The *Sucker* is an aerial shoot that springs from an underground branch. This form of stem is also illustrated in the Raspberry.

The *Offset* is either a short sucker or a short stolon, and is illustrated in the common Houseleek.

The *Runner* is such a creeping and rooting stem as that of the Strawberry, Fig. 19.

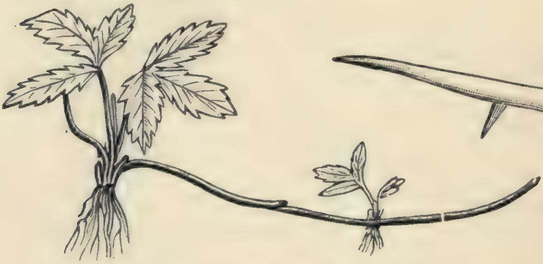


FIG. 19.—Strawberry plant producing a runner.

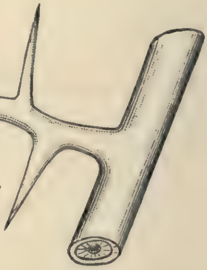


FIG 20.—Branching thorn of the Honey-locust.

The *Thorn* or *Spine* is a stem modification which is hard, pointed and destitute of leaves, or nearly so; for example, the thorns of the Honey Locust, Fig. 20. Not all spines, however, are modified stems; some are modified leaves or portions of leaves.

UNDERGROUND STEMS.

The stems so far described are all aerial or above ground, but there are also *subterranean* ones, which mimic the habits of roots. They may readily be distinguished from the latter by the fact that they bear scales or scale scars, in the axils of which buds not infrequently occur, and also by the fact that the growing-point is situated at the apex instead of just back of it. Its growing end is enveloped in scales, the representatives of leaves; it, therefore, like the above-ground stem, possesses a terminal bud. Various kinds of subterranean stems are distinguished, the more important of which are the following:

The **Rhizome** is a creeping, underground stem, which grows horizontally or obliquely, is more or less scaly or marked with the scars of scales, sends off roots usually more abundantly from the under surface, and commonly has its upper surface more or less distinctly marked with the scars or withered remains of the bases of aerial stems of previous years. The terminal bud is usually conspicuous. A rhizome may either be slender and extensively creeping, as in Couch-grass and Carex, Fig. 21, or thickened and fleshy, as that of Solomon's Seal, Fig. 22.

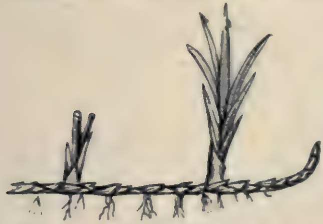


FIG. 21.—Creeping rhizome of a species of Carex.

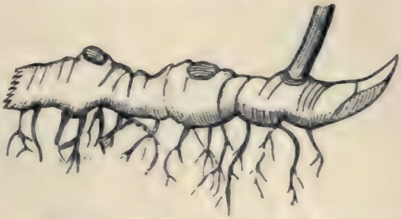


FIG. 22.—Thickened rhizome of Solomon's Seal.

The Tuber is a short and excessively thickened underground stem, borne usually at the end of a slender, creeping branch. The tubers of the Artichoke and Potato, Fig. 23, are examples. The creeping branches usually perish in autumn, setting the tubers free from the parent plant. Since they grow in the spring and produce new plants, they are efficient means of propagating the species. They may readily be distinguished from tuberous roots like those of the Sweet-potato, by the "eyes," which are axillary buds.

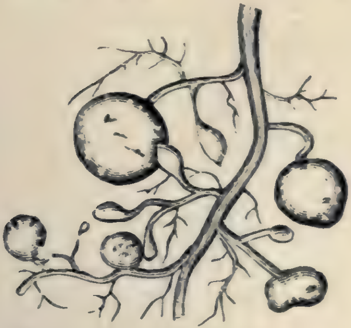


FIG. 23.—Tubers of the Potato in various stages of development.

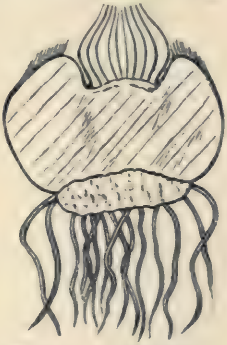


FIG. 24.—Longitudinal section of the corm of the Crocus.

The Corm is an excessively thickened, erect, underground stem, covered with thin leaf-scales on the surface. The corms of Crocus and Colchicum are examples. Fig. 24 is a longitudinal section of a Crocus corm. At the base is a partially decayed corm of the previous year, and at the apex a large bud.

The Bulb is an excessively short, erect stem, covered with fleshy scales or leaf-bases, which constitute its principal bulk. A bulb whose leaf-bases form concentric coatings is called a *tunicated bulb*, and one whose scales are imbricated, the outer ones not enclosing the inner, is called a *scaly bulb*. The Onion, Fig. 25 is an example of the former, and the Lily, Fig. 26, of the latter.

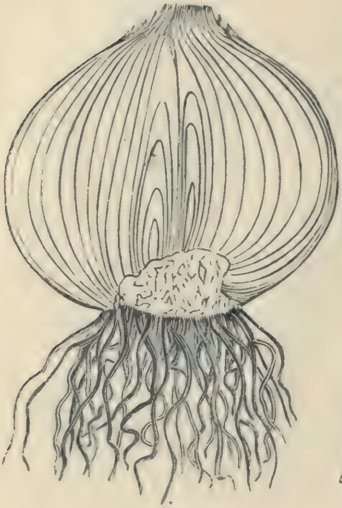


FIG. 25.

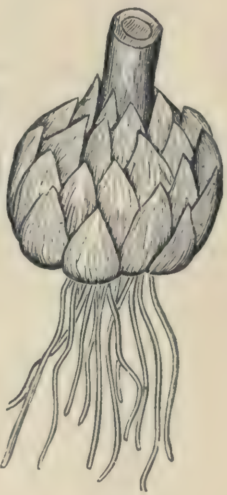


FIG. 26.

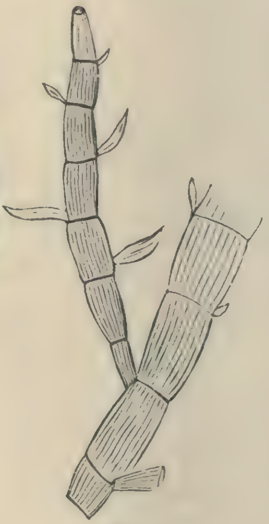


FIG. 27.

FIG. 25.—Longitudinal section of the Onion, showing the structure of a tunicated bulb.
FIG. 26.—The scaly bulb of the Lily.
FIG. 27.—Portion of flattened stem and leaf-like branches of Mühlenbeckia.

LEAF-LIKE STEMS.

Stems occasionally mimic leaves, both in form and function. This is the case with the leaf-like bodies on the stem of the greenhouse Smilax (Myrsiphyllum). Such stems are called *cladophylla*, and that they are really stems or branches and not leaves is evidenced by the fact that they occur in the axils of scales; are the product, that is, of axillary buds. Fig. 27 represents a flattened branch of Mühlenbeckia, which performs at once the functions of leaf and stem, though true leaves are also present. The stems of Cactuses also frequently assume leaf-like forms and perform the functions of leaves, the leaves themselves being present in the form of spines. In Duckweed the functions of leaf and stem appear never to have been differentiated. An organ so constituted, and which is, properly speaking, neither leaf nor stem, is termed a *thallus* or *frond*, Fig. 28. It is a rare thing among flowering plants to find leaf and stem thus blended or undifferentiated, but it is very common among flowerless plants.

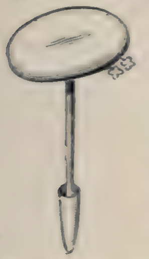


FIG. 28.—The common Duckweed, the upper disc-like portion or frond bearing marginal flowers, and sending down a root with a prominent root-cap, from the under surface.

PRACTICAL EXERCISES.

1. Gather twigs of six or more different trees, such as occur in your neighborhood, for instance, the Sugar Maple, the American Elm the Bass-wood, the Locust, the Cotton-wood and the Horsechestnut. It will be better for the purpose of this exercise if they be gathered in the late autumn or early spring. Observe the leaf-scars and their arrangement on each twig. Observe the terminal and lateral buds of each, and note in each instance which are the stronger or better developed; note the positions of the lateral buds relative to the leaf-scars in each case; note which of the trees bear scaly and which naked buds; selecting the twigs that have the largest buds, dissect carefully the terminal buds of each, observing, by means of the magnifying glass, the position, structure and arrangement of the bud-scales and of the true leaves which they enclose; note how the scales are adapted in each case to the purpose of protection, and, lastly, observe the area on the twig ringed by the scars of the bud-scales of the previous year, and answer, if you can, the question why this part of the twig did not elongate the same as that portion of it which bore the true leaves.

2. Cut off most of the blade of a leaf of the common Begonia, leaving only the basal portion and the petiole, and plant it in damp sand, keeping it moist and at a temperature of about 90° F., for a few days. If the experiment has been properly conducted adventitious buds will make their appearance in the axils of the veins.

Study the supernumerary buds on twigs of the Apple, Lilac and Butternut or Hickory, and note the difference of arrangement.

3. Compare the shapes of the stems of the Bulrush, the Wheat, Peppermint, Yellow Dock, Wild Parsnip, Prickly-pear Cactus and other familiar plants. Observe the twining stems of the Hop and Morning-glory, and note how they differ in their modes of twining. Observe how the Blackberry, the Wild Clematis, the Poison Rhus, the Virginia Creeper, the Pumpkin, the Pea and the Green-briar differ in their climbing organs and in their modes of climbing.

Observe the defensive organs of the Gooseberry. Are they all of the same kind or not? Are they modified branches or not? Examine branches of the Barberry and Hawthorn, and determine the nature of their thorns, whether they are modified leaves or modified branches.

4. Pull up the following plants by the roots, and examine the underground parts, determining whether they are roots, rhizomes, corms, tubers or bulbs, and give the reasons for your conclusion: Wild or Indian Turnip, Common Blue Violet, Dandelion, Wild Hyacinth, Blood-root and Sweet-flag. Make a careful dissection of an Onion bulb and a Crocus corm, and ascertain how they differ; also make a careful comparative study of the Sweet-potato and the Irish potato.

CHAPTER III.—THE LEAF.

Leaves may be defined as *stem-appendages which have their origin just back of the apex of the stem, are regularly arranged upon it, and consist of expansions of its tissues.*

They are never directly borne by roots or by any other organs except the stem. Foliage leaves, which may be taken as the type, are, in the majority of cases, flattened, bi-laterally symmetrical, expanded organs, green in color and presenting a distinct upper and under surface. They differ usually from stems by maturing or completing their growth first at the apex, and afterwards at the base, but in Ferns and in some compound-leaved Dicotyledons the basal portion matures first while the apex continues to grow. The primary function of foliage leaves is that of elaborating the plant food. They are pre-eminently the assimilative or digestive organs of the plant. Leaves exist in numerous forms other than that of foliage, and in many instances perform functions altogether different. Several different modifications of leaves may often be observed on the same plant. Indeed, there is no organ of the plant body which subserves so many different uses or exists under such a variety of disguises. But, however different their forms and functions may be at maturity, they are alike in the earliest stages of their growth, that is, in the very young bud. At this period of their development, a leaf which is destined to become a spine, a tendril, a stamen or a pistil, cannot be distinguished from one that is to become a foliage leaf. All alike begin as minute papillæ or protuberances just back of the growing apex of the stem. Moreover, they always appear in acropetal order, that is, the older ones are lower down, and, as the stem elongates, younger ones are found higher up on the stem.

Prefoliation or Vernation. By this is meant the arrangement of the leaves in the bud, a matter of considerable importance to observe in the study of plants. We may study it from two points of view; we may consider the individual leaf, how it is folded, bent or rolled, or we may consider how the leaves are arranged with reference to each other.

Studying the individual leaf, we distinguish the following forms: If the apex is bent inward toward the base, as the leaf of the Tulip-tree, Fig. 29, it is described as *reclinate* or *inflexed;* if it is doubled inward on the midrib, so that the two sides are applied to each other, face to face, as in the Oak, Fig. 30, it is called *conduplicate;* when rolled inward from one margin to the other, as in the Wild Cherry, Fig. 31, it is said to be *convolute;* when rolled inward from the apex toward the base, as in the Sundew and in Ferns, Fig. 32, it is called *circinate;* when, as in the Birch, Fig. 33, it is folded somewhat like the folds of a fan, it is described as *plicate;* when, as in the common Violet, Fig. 34, it is rolled inward from each margin it is termed *involute;* and when, as in Yellow Dock, Fig. 35, it is rolled outward from each margin, it is called *revolute.*

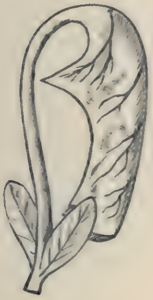
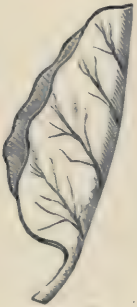


FIG. 29.



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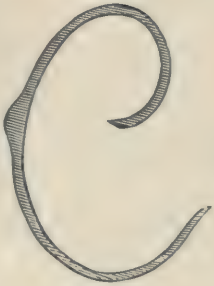


FIG. 31.

FIG. 29.—Young leaf of the Tulip-tree, illustrating reclinate or inflexed vernation.
FIG. 30.—Young leaf of Oak, illustrating conduplicate vernation.
FIG. 31.—Transverse section of a young leaf of the Wild Cherry, illustrating convolute vernation.

It must be borne in mind that in botanical usage the inner surface of the leaf is that which, in the majority of flattened leaves, constitutes the upper surface when fully expanded ; it is also called the *ventral* surface, and the outer is termed the *dorsal.*

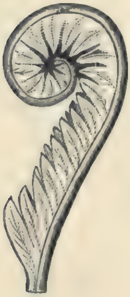


FIG. 32.

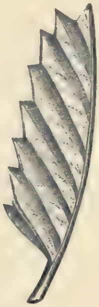


FIG. 33.

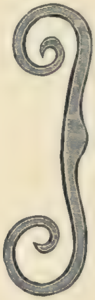


FIG. 34.

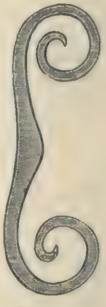


FIG. 35.

FIG. 32.—Young Fern leaf, illustrating circinate vernation.
FIG. 33.—Young leaf of the Birch, illustrating plicate vernation.
FIG. 34.—Transverse section of the young leaf of the common Violet, illustrating involute vernation.
FIG. 35.—Transverse section of the young leaf of Yellow Dock, illustrating revolute vernation.

When considered with reference to each other, several distinct forms of prefoliation are also observed : It is *equitant* when, as in the Iris, the leaves are conduplicate, and those exterior override or straddle successively both margins of the ones next interior to them, Fig. 36 ; it is called *obvolute* or *half-equitant* when, as in the Sage, the leaves are conduplicate, and each

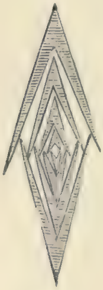


FIG. 36.

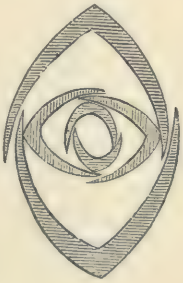


FIG. 37.

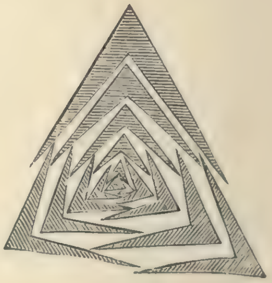
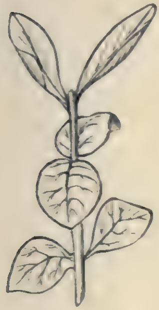


FIG. 38.

FIG. 36.—Diagram illustrating equitant vernation.
FIG. 37.—Diagram of obvolute or half-equitant vernation. Leaves of Sage.
FIG. 38.—Diagram of triquetrous vernation. Leaves of Sedge.

leaf embraces or straddles only one margin of the other, Fig. 37; and it is said to be *triquetrous* when, as in the Sedges, Fig. 38, the leaves are conduplicate, and so arranged that the bud is triangular in cross-section. Other modes of the disposal of leaves with reference to each other will be considered under æstivation or prefloration, when we come to the study of the flower.

Phyllotaxy. This term has reference to the arrangement of leaves on the stem. It is important to observe that they do not occur at random on a stem or branch, but in a definite order, although the order varies in different plants, and sometimes is different on different parts of the same plant.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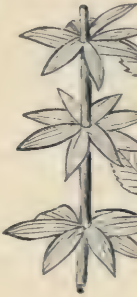


FIG. 40.

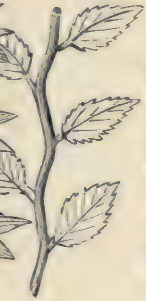
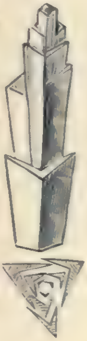


FIG. 41.


FIGS. 42 and 43.

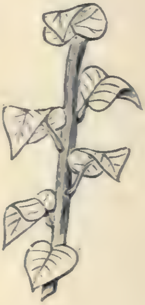


FIG. 44.

FIG. 39.—Branch of Privet, showing the opposite and decussate leaves.
FIG. 40.—Whorled leaves of the Canada Lily.
FIG. 41.—Branch illustrating the alternate, ½ or distichous arrangement of leaves.
FIG. 42.—Portion of stem of Carex, with leaves partially cut away, showing the ⅓ or tristichous arrangement.
FIG. 43.—Transverse section of leaves of Carex, showing tristichous arrangement.
FIG. 44.—Branch showing $\frac{2}{5}$ or pentastichous arrangement of leaves.

There are two general plans of phyllotaxy; first, the *whorled* or *verticillate*, and second, the *alternate* or *scattered*.

In the WHORLED plan two or more leaves occur at a node or on the same level, as in Figs. 39 and 40. Where there are but two leaves at a node they are almost invariably situated 180° apart, that is, the circumference of the stem is equally divided between them, and the leaves are said to be *opposite*.

Opposite leaves are usually *decussate*, that is, the second pair stand over the intervals between the first pair, as in Fig. 39.

Usually, also, when there are three leaves in the whorl, they are one-third of the circumference of the stem apart; when four, one-fourth, and so on, and as a general rule also the leaves of successive whorls stand over the interspaces of those immediately below them. Good examples of opposite leaves are those of the Mints, Maples and Lilac, and of whorled leaves in which there are more than two leaves in the whorl, the Galiums, Canada Lily, Leptandra and Silene stellata afford good illustrations.

In the ALTERNATE or scattered plan but one leaf occurs at a node, and the leaves succeed each other in a spiral order.

It is much the more common mode of phyllotaxy, and a considerable number of different forms of it are recognized, the greater portion of which may be reduced to a series mathematically represented by the fractions $\frac{1}{2}$, $\frac{1}{3}$, $\frac{2}{5}$, $\frac{3}{8}$, $\frac{5}{13}$, etc. In these fractions the numerator represents the number of turns to complete a cycle, that is, to reach a leaf which stands directly above the first; the denominator represents the number of *orthostachies* or perpendicular rows of leaves on the stem, or, what is the same thing, the number of leaves, counting along the spiral from any one of them, to the one which stands directly above it; and the whole fraction expresses the angular distance measured circumferentially on the stem from one leaf to the next one on the spiral.

It will be observed also that the third fraction of the series is derivable from the first two by adding together the numerators for a new numerator and the denominators for a new denominator; that the fourth is derived from the second and third in the same way, and so on.

Examples of the $\frac{1}{2}$ or *distichous* arrangement occur in the Elm and Basswood, and it prevails in the whole family of Grasses; it is illustrated in Fig. 41. The $\frac{1}{3}$ or *tristichous* arrangement occurs in the Sedges, as shown in Figs. 42 and 43; the $\frac{2}{5}$ or *pentastichous* arrangement occurs in many common trees, as the Cherry and Apple, and is illustrated in Fig. 44; the $\frac{3}{8}$ or *octastichous* arrangement is observed in Aconite, Osage Orange, Plantain and Holly; the more complex plans are rarer, but the $\frac{5}{13}$ is observed in the Houseleek and some other plants, and arrangements represented by this and fractions still higher in the series occur in the cones of various species of pines, spruces, etc.

Even where the leaves are compactly clustered or *fascicled*, as in the Larch, Fig. 45, and some other trees, careful examination reveals the fact that the arrangement is really a spiral one.

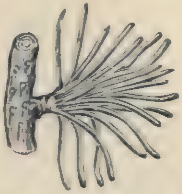


FIG. 45.—Portion of twig of Larch, showing fascicled leaves.

It is not uncommonly the case, of course, that in a mature branch we find some slight deviations from regularity in the arrangement of leaves, but these are of such a character that they may readily be accounted for, either by the distortions which stems frequently undergo during the process of growth, or by the failure of some of the leaves to develop.

It will be seen that since branches usually spring from axillary buds, their arrangement must also be regular and correspond in plan with that of the phyllotaxy.

Duration of Leaves. Leaves differ widely as to their period of duration. They are described as *persistent* or evergreen, if they remain green and on the tree for a year or more; they are *deciduous*, if unfolding in the spring or summer, they fall off in the autumn or the season of frosts; and if falling off early in the season, as is the case with bud-scales, and often also with other imperfect leaves, they are described as *fugacious* or *caducous*.

As now in tropical regions evergreen trees are much the more common, while in our own climate they are rare, there is good reason to believe that in the warm ages of the world preceding the ice period, all trees were evergreens, and that our northern trees have become deciduous-leaved by gradual adaptation to the vicissitudes of the climate.

Position. According to their place of insertion on the stem, leaves often differ from each other considerably in form and appearance, and it is often, therefore, convenient to use special terms indicative of their position. *Cauline* leaves are those which are inserted on the main stem; *rameal* leaves are those borne on the branches; *radical* leaves are those which spring from the basal portion of the stem at or just beneath the ground; *seminal* or *primordial* leaves are those which are borne by the embryo in the seed; and *floral* leaves are the leaves of the flower.

Parts and Structure of Leaves. A leaf, when complete, consists of three parts, the *lamina* or blade, the *petiole* or leaf-stalk, and two small blade-like bodies at the base of the petiole called the *stipules.* Such a leaf is seen in the Tulip-tree, and is illustrated in Fig. 46. Frequently some of these parts are wanting. The stipules, being least serviceable to the plant, are most frequently absent; in this case the leaf is described as *exstipulate;* not uncommonly the petiole is wanting and the blade is inserted directly upon the stem; it is then described as *sessile;* sometimes the blade is not merely sessile, but more or less embraces the stem at the base, when it is called *clasping;* sometimes it grows quite around the stem, and its edges even coalesce on the opposite side, so that the stem appears to grow through its base, as in the Bell-wort, Fig. 47, when it is described as perfoliate; sometimes, in the case of opposite leaves, the bases grow together or become coherent, apparently forming a single leaf, with the stem passing through its middle, as in the Cup-plant, the Boneset, and the Wood-bine or Honeysuckle, Fig. 48, in which case they are called *connate*, and sometimes the margins of the

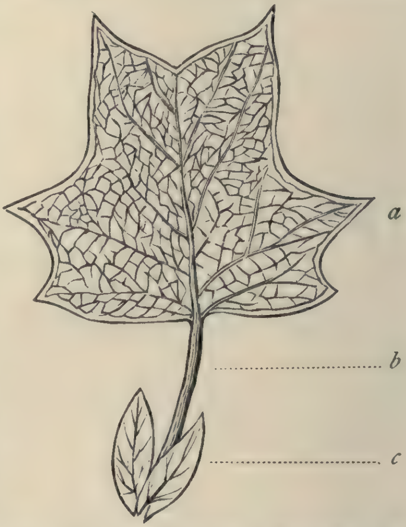


FIG. 46.—Leaf of Tulip-tree, illustrating the parts of a complete leaf. The upper part, *a*, is the lamina, and below is the petiole, *b*, at the base of which are the two stiples, *c*.

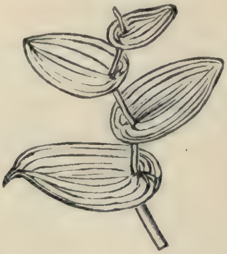


FIG. 47.

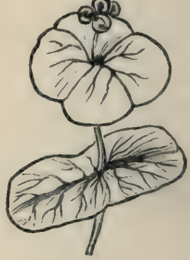


FIG. 48.

FIG. 47.—Part of stem of Uvularia, illustrating perfoliate leaves.

FIG. 48.—Connate leaves of the Honeysuckle.

leaf grow down the sides of the stem, or become *decurrent*, as in the Mullein, the Sneeze-weed and the Comfrey, Fig. 49.

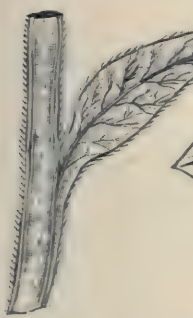


FIG. 49.

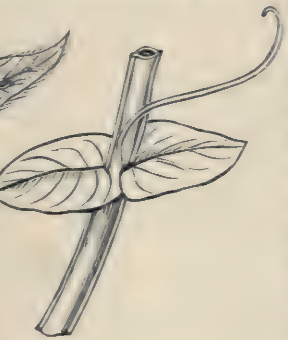


FIG. 50.

FIG. 49.—Decurrent leaf of Comfrey.

FIG. 50.—Portion of stem of Lathyrus aphaca, one of the Pulse family, showing stipules which perform the functions of a leaf-blade while the blade proper is developed into a tendril.

But even the blade, although the most important part, may be wanting or developed into some form different from the ordinary one, while either the stipules or the modified petiole performs its functions. Lathyrus aphaca, Fig. 50, is an example of a leaf in which the stipules become strongly developed and perform the functions of blades, while the petiole and blade proper are

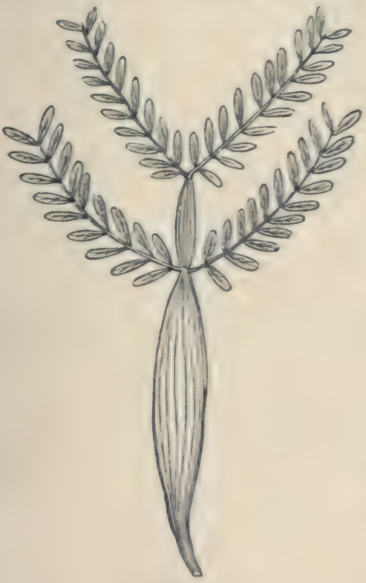


FIG. 51.

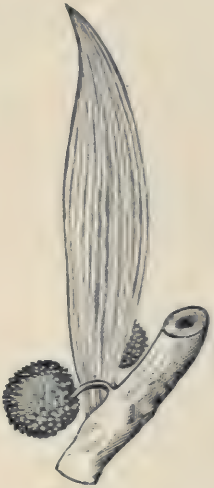


FIG. 52.

FIG. 51.—Leaf of Australian Acacia, showing tendency to abortion of leaf-blade and the development of the petiole into a phyllode.

FIG. 52.—Fully developed phyllode of Australian Acacia.

modified into a tendril for the purpose of enabling the plant to climb.

In most of the Australian Acacias, trees which in other countries are noted for their graceful, feathery foliage, both blade and stipules of all but the earlier leaves fail to develop, while the petiole becomes flattened and performs the functions of a blade. These flattened petioles, or *phyllodia*, as they are called, are simple, parallel-veined, and placed with their edges vertical; hence the Australian species present a widely different appearance from the nearly related ones of other countries. Fig. 51 represents one of the earlier leaves of one of these Acacias, showing a widened petiole, and the tendency to develop phyllodia, and Fig. 52 represents a fully formed phyllodium of the same tree.

It is frequently the case, however, that all parts may be present, but, owing to a change in their usual form, or a partial coalescence with other parts, the presence of one or the other of them may be more or less obscured. In grasses, for example, the stipules appear to be united with the petiole to form the *sheath* which clasps or encloses the stem, but usually their apices are free and slightly project at the junction of the blade and sheath, forming what is called the *ligule*, Fig. 53.

In the Polygonums the stipules cohere with each other, and form a sheath about the stem. This stipular sheath, which is usually membranous, and may or may not have a free portion, is called the *ochrea*. Not infrequently also the stipules become adnate to the petiole, as in the Rose, Fig. 54, or become converted into spines, as in the Locust, Fig. 55, and in some instances they are changed into tendrils, as in the Green Briar, Fig. 56. In many instances also they are scaly, and after serving the purpose of protection in the bud, fall away when the leaves expand.

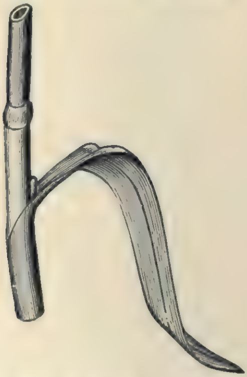


FIG. 53.—Leaf of grass, showing lamina, sheath and ligule.

Considering the structure of the parts of the leaf, we find the blade and stipules, when normally developed, consist of a tough framework or system of *veins*, which serves partly for support and partly to conduct the nutritive fluids; an intervening soft tissue called the *mesophyll*, or leaf-parenchyma, and an epidermis which covers the whole. The petiole consists more largely of fibrous tissue, the continuation of the framework of the blade, and possesses comparatively little parenchyma.

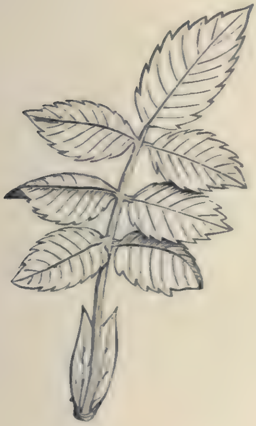


FIG. 54.

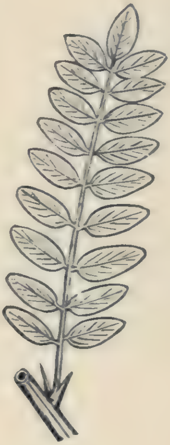


FIG. 55.

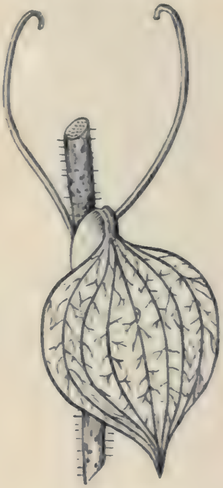


FIG. 56.

FIG. 54.—Adnate stipules of Rose.
FIG. 55.—Stipules of the common Locust converted into spines.
FIG. 56.—Stipules of Green Briar (Smilax) developed into tendrils.

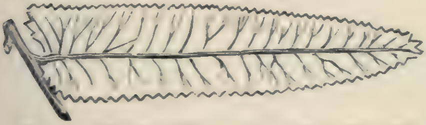


FIG. 57.—Pinnule of Osmunda regalis, a Fern, illustrating furcate venation.

The Venation of Leaves. By this is meant the arrangement of the veins or framework. In such simple leaves as many of the Mosses, no veins are present, and the leaf consists merely of a layer of green cells, but in higher plants a venation is always more or less distinctly recognizable. Three different types of it are distinguished, the *furcate* or forked venation, in which the veins fork or divide once or repeatedly into equal divisions, as seen in many ferns and other cryptogamous plants, but seldom in flowering plants, see Fig. 57; the *nerved* or *parallel-veined* plan, the common form observed in Monocotyledons, as Grasses, Palms, Lilies, etc.; and the *reticulate*, or netted-veined plan, the type which prevails in Dicotyledonous plants, such as the Roses, Maples, Oaks, etc.

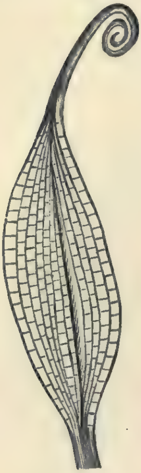


FIG. 58.

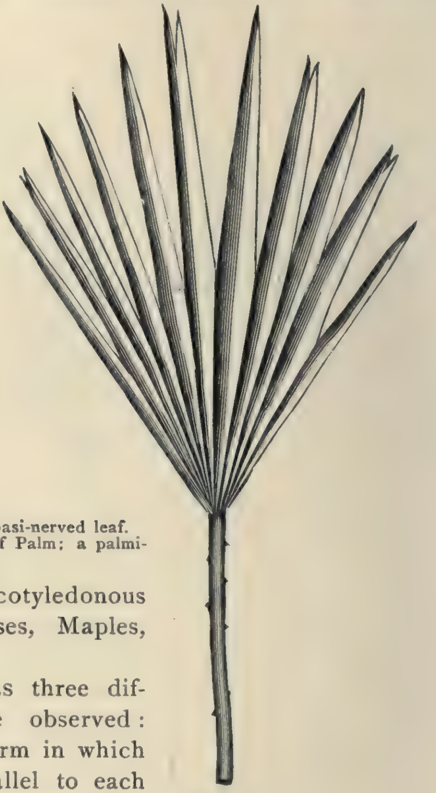


FIG. 59.

FIG. 58.—The leaf of Gloriosa; a basi-nerved leaf.
FIG. 59.—The leaf of a species of Palm; a palmi-nerved leaf.

Among NERVED LEAVES three different modifications are observed: (1) The *basi-nerved*, a form in which the veins run nearly parallel to each other from the base to the apex of the leaf. Such leaves incline to elongated forms, and the type is well illustrated in most grasses, and in the Gloriosa Lily, Fig. 58. (2) The *palmi-nerved* leaf, in which the veins are straight and radiate from the petiole to the margin of the blade. Such leaves incline to rounded forms. The type is illustrated in the leaf of the Fan Palm, Fig. 59. (3) The *pinni-nerved* leaf, in which there is a mid-rib or vein running from the base to the apex of the leaf, and straight or somewhat curved veins running from this, nearly parallel to each other, to the margin, as seen in the Banana and the Calla (Richardia Æthiopica), Fig. 60.

In the *reticulate* plan the veins branch repeatedly, and the veinlets, or small branches of different veins, run together end to end, or anastomose, forming a more or less complicated network. There are also three modifications of this type: (1) The *pinni-reticulate*, or pinnately netted, in which there is a mid-rib with lateral branches which run toward the margin, branching repeatedly and forming a network, as in Fig. 61; (2) the *palmi-reticulate*, or radiately netted, a reticulate leaf in which there are several ribs radiating from the petiole to the margin, as in the leaf of the White Poplar, Fig. 62, and (3) the *costate-reticulate* or ribbed-netted leaf, in which there are several prominent veins or ribs running from base to apex of the leaf, with a network of small veins between, as in the leaf of the Wild Yam, Fig. 63. The first and third varieties incline to elongated and the second to rounded forms, though there are some exceptions to the rule.

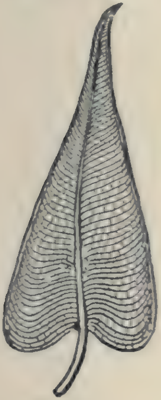


FIG. 60.

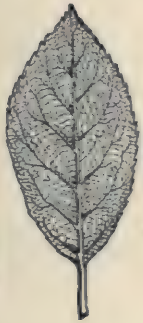


FIG. 61.

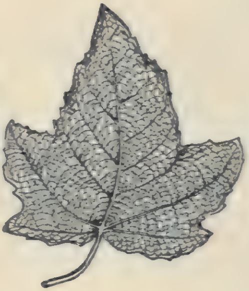


FIG. 62.

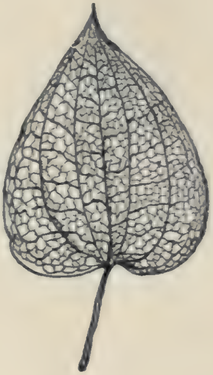


FIG. 63.

FIG. 60.—The leaf of the Calla; a pinni-nerved leaf.
FIG. 61.—The leaf of Carpinus; a pinni-reticulate leaf.
FIG. 62.—The leaf of the White Poplar; a palmi-reticulate leaf.
FIG. 63.—The leaf of the Wild Yam; a costate-reticulate leaf.

THE FORMS OF LEAVES.

Since leaves, like other organs of the plant, may remain simple or branch, we may conveniently classify them into *simple* and *compound* forms. The shapes of each are very numerous, and as they often afford characters by means of which plants are distinguished, it is important for the student to be familiar with the more common forms and the terms used in describing them. For the most part leaves, whether simple or compound, incline to bi-laterally symmetrical forms, that is, the two sides of the leaf are counterparts of each other in size and shape, but it sometimes occurs, as in the Begonias, Fig. 64, that one side is much better developed than the other. Such leaves are termed *inequilateral.* It not infrequently happens that the bases of simple leaves and the leaflets of compound ones show a slight inequality.

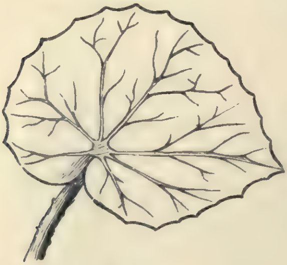


FIG. 64.

Simple Leaves. A simple leaf is one which has a single blade, which may either be sessile or petiolate, but if the latter, petiole and blade are united directly and not by means of a joint. We may conveniently describe simple leaves and the separate blades of compound leaves, as to *general outline*, *apex*, *base*, *marginal indentations*, *surface* and *texture.*

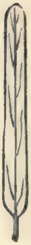


FIG. 65.

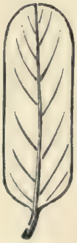


FIG. 66.

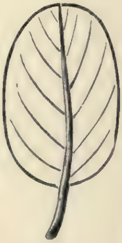


FIG. 67.

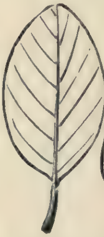


FIG. 68.

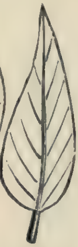


FIG. 69.

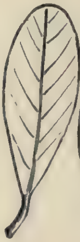


FIG. 70.

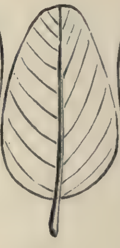


FIG. 71.

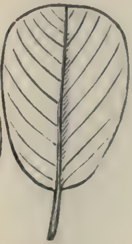


FIG. 72.

(a) *General Outline.* By this we mean the outline form of the leaf, disregarding marginal indentations and slight irregularities. The principal forms are the *linear*, a narrow, elongated form, with parallel margins, as represented in Fig. 65; the *oblong*, which is broader, but considerably longer than wide, with sides nearly parallel and ends rounded, Fig. 66; the *elliptical*, somewhat longer than wide, with rounded ends and sides, Fig. 67; the *oval*, or broadly elliptical, Fig. 68; the *lanceolate*, or lance-shaped, Fig. 69; the *oblanceolate*, or inversely-lance-shaped, Fig. 70; the *ovate*, which is shaped like the longitudinal section of a hen's egg, and has the petiole at the larger end, Fig. 71; the *obovate*, or inversely ovate, as in Fig. 72; the *spatulate*, which is larger and rounded at the apex, and tapering at the base like the old-fashioned spatula, Fig. 73; the *panduriform*, or fiddle-shaped, Fig. 74; the *orbicular*, which is nearly circular in outline, Fig. 75; the *ensiform*, or sword-shaped, as in the Iris, Fig. 76; the *subulate*, or awl-shaped, as the leaves of Arbor Vitæ and Cedar, Fig. 77; and the *filiform*, or thread-shaped, proportionately very long and narrow, as the leaves of Asparagus.

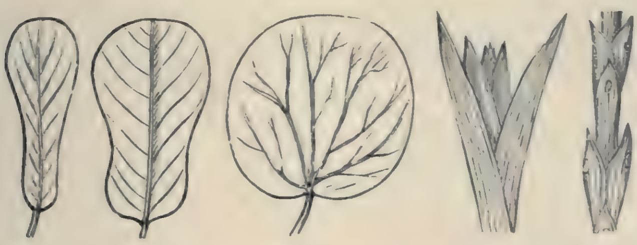


FIG. 73. FIG. 74. FIG. 75. FIG. 76. FIG. 77.

FIGS. 65 to 77, inclusive, diagrams illustrating forms of leaves as respects general outline; 65, linear; 66, oblong; 67, elliptical; 68, oval; 69, lanceolate; 70, oblanceolate; 71, ovate; 72, obovate; 73, spatulate; 74, panduriform; 75, orbicular; 76, ensiform; 77, subulate.

(b) *The Apex.*—As regards the shape of the apex, the following are the more important forms: The *obcordate*, or inversely heart-shaped, Fig. 78; the *emarginate*, or notched, Fig. 79; the *retuse*, with a broad, shallow sinus at the apex, Fig. 80; the *aristate*, with the apex terminating in a bristle, Fig. 81; the *mucronate*, with the apex terminating in an abrupt, soft point, Fig. 82; the *cuspidate*, the same as mucronate, but with a hard point; the *truncate*, with the apex terminating abruptly, as if cut

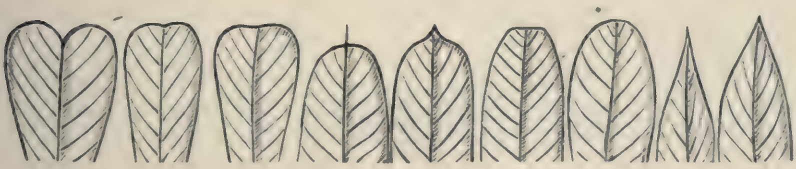
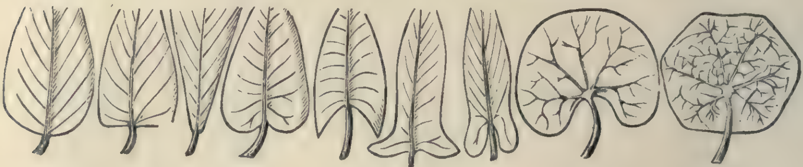


FIG. 78. FIG. 79. FIG. 80. FIG. 81. FIG. 82. FIG. 83. FIG. 84. FIG. 85. FIG. 86.

FIGS. 78 to 86, inclusive, diagrams illustrating forms of leaf apices: 78, obcordate; 79, emarginate; 80, retuse; 81, aristate; 82, mucronate (or if the point be hard, cuspidate); 83, truncate; 84, obtuse; 85, acuminate; 86, acute.

off, Fig. 83 ; the *obtuse*, with a rounded or blunt apex, Fig. 84; the *acuminate*, or taper-pointed, Fig. 85 ; and the *acute*, with an apex which forms an acute angle, Fig. 86.

(c) *The Base.* As respects the shape of the base the following are the most common forms : The *rounded*, or obtuse, Fig. 87 ; the *truncate*, Fig. 88 ; the *cuneate*, or wedge-shaped, Fig. 89 ; the *cordate*, or heart-shaped, Fig. 90 ; the *sagittate*, or arrow-shaped, Fig. 91 ; the *hastate*, or halberd-shaped, Fig. 92 ; the *auriculate*, when there are two ear-like appendages at the base, Fig. 93 ; *reniform*, or kidney-shaped, Fig. 94 ; and the *peltate*, or shield-shaped, where the petiole is attached near the centre of the blade, as in Fig. 95.



FIGS. 87. 88. 89. 90. 91. 92. 93. 94. 95.

FIGS. 87 to 95, inclusive, diagrams illustrating forms of leaf bases ; 87, rounded or obtuse ; 88, truncate ; 89, cuneate ; 90, cordate ; 91, sagittate ; 92, hastate ; 93, auriculate ; 94, reniform ; and 95, peltate.

(d) *Marginal Indentations.* Here we may distinguish between indentations that are shallow, extending considerably less than half way to the mid-rib or to the base (if radially indented) and those which are deeper.

Among the more important forms with shallow indentations are the following : The *serrate*, or saw-toothed, with sharp teeth which incline forward like the teeth of a hand-saw, the *serrulate*, or minutely saw-toothed, and the *bi-serrate*, or doubly serrate, with two sets of teeth, one upon the other, see Fig. 96 ; the *dentate*, or toothed with outwardly projecting teeth, the *denticulate*, or finely dentate, and the *bi-dentate*, or doubly-dentate (the three forms are illustrated in Fig. 97) ; the *crenate*, or scalloped, the *crenulate*, or minutely crenate, and the *bi-crenate*, or doubly-crenate (illustrated in Fig. 98) ; the *undulate*, or wavy ; the *sinuate*, or deeply-wavy, and the *repand*, or undulate-dentate, with a margin like that of an umbrella, Fig. 99. Other forms are the *crenate-dentate*, or scalloped, with the scallops produced into sharp teeth, as in Fig. 100; the *spinose*, with the margin spiny, Fig. 101; the *ciliate*, with the margin fringed with hairs; the *fimbriate*, with the margin cut into slender segments or fringed, and the *crispate*, with the margin crisped, as in Fig. 102.

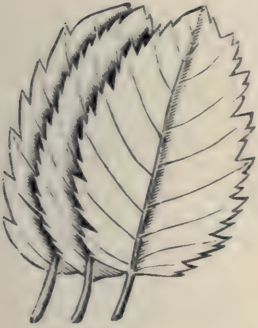


FIG. 96.

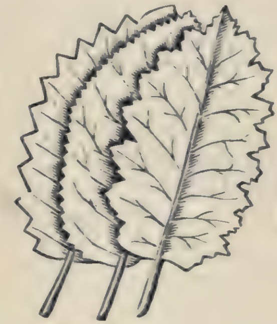


FIG. 97.

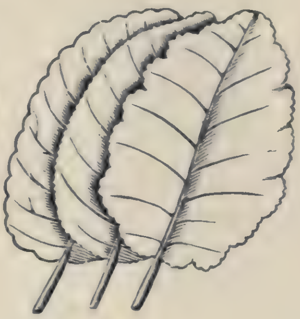


FIG. 98.

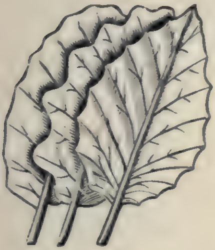


FIG. 99.

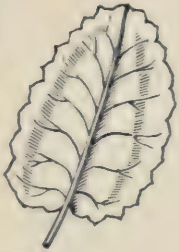


FIG. 100.

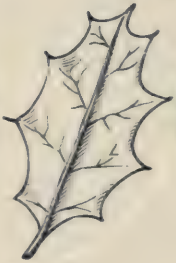


FIG. 101.

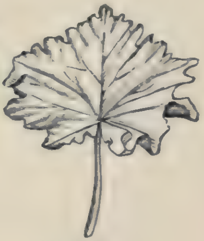


FIG. 102.

FIGS. 96 to 102 inclusive, diagrams illustrating marginal indentations of leaves: 96, serrate, serrulate and bi-serrate; 97, dentate, denticulate and bi-dentate; 98, crenate, crenulate and bi-crenate; 99, undulate, sinuate and repand; 100, crenate-dentate; 101, spinose; and 102, crispate.

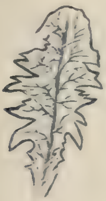


FIG. 103.

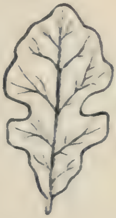


FIG. 104.

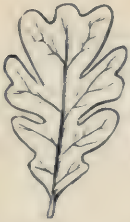


FIG. 105.

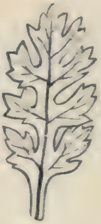


FIG. 106.

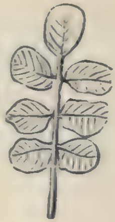


FIG. 107.

FIGS. 103 to 107 inclusive, diagrams illustrating the deeper marginal indentations in pinnately-veined leaves: 103, runcinate; 104, pinnately-lobed; 105, pinnately-cleft; 106, pinnately-parted, and 107, pinnately-divided.

The commoner forms with deeply indented margins, are the following: The *incised* is one in which the margin is jagged, or irregularly and rather deeply cut, as if cut with a knife. The peculiar form of pinnately-incised leaf observed in the Dandelion and some other Compositæ, Fig. 103, in which the teeth are recurved, is called *runcinate.* The *lobed* is one in which the indentations extend nearly half way to the mid-rib or base, and in which either the segments or sinuses, or both, are rounded as in the leaves of some Oaks, Fig. 104; the *cleft* is the same as lobed, except that the sinuses are deeper and commonly acute, Fig. 105; the *parted* is one in which the incisions, of whatever form, extend nearly but not quite to the mid-rib, as in the leaf of the Poppy, Fig. 106; and the *divided* is one in which the incisions extend quite to the mid-rib, but the segments are unstalked, as in the leaf of the Cress, Fig. 107.

It is evident that if the venation is pinnate, the series of forms may be described as pinnately-incised, -lobed, -cleft, -parted or -divided, as in the series of figures from 103 to 107 inclusive. If, however, the venation is radiate, as in the series of figures from 108 to 112 inclusive, they will be described as radiately or palmately-incised, -lobed, etc.

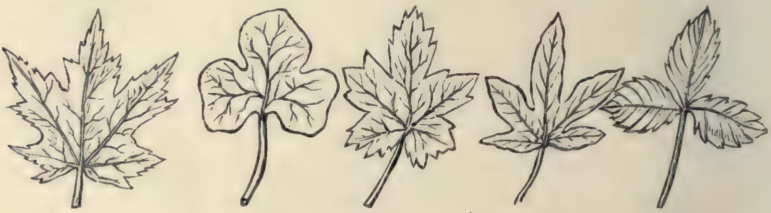


FIG. 108. FIG. 109. FIG. 110. FIG. 111. FIG. 112.

FIGS. 108 to 112 inclusive, diagrams illustrating the palmately-veined leaves with deep marginal indentations; 108, palmately-incised; 109, palmately-lobed; 110, palmately-cleft; 111, palmately-parted, and 112, palmately-divided.

The terms *pinnatilobate*, *pinnatifid*, *pinnatipartite* and *pinnatisect* are used synonymously with pinnately-lobed, pinnately-cleft, pinnately-parted and pinnately-divided, respectively. The corresponding terms descriptive of the radiate or palmate forms are *palmatilobate*, *palmatifid*, *palmatipartite* and *palmatisect.*

The number of lobes, segments or divisions may be indicated by appropriate numerical prefixes, thus: *Bilobate*, *trilobate*, *multilobate*; *bifid*, *trifid*, *multifid*; *bipartite*, *tripartite*, *multipartite*; *bisect*, *trisect*, *multisect*, etc.; and in case it is desired at the same time to indicate the arrangement of the segments or lobes, the modifying adverbs pinnately and palmately, or radiately, may be used, as *pinnately quadrifid*, *palmately multisect*, *radiately trilobate*, etc.

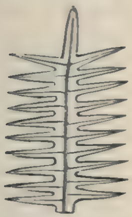


Fig. 113.

A leaf which is pinnately-parted in such a manner that the divisions are linear and stand out from the axis, parallel to each other, as the teeth of a comb, is commonly described as *pectinate*, see Fig. 113. Leaves which are separated into numerous irregularly branching divisions are described as *dissected*, and such leaves may be either *palmately-dissected*, as the submerged leaves of the Yellow Water Ranunculus, Fig. 114, or *pinnately-dissected*, as the leaves of Chamomile, Fig. 115.

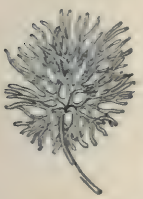


Fig. 114.

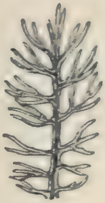


Fig. 115.

Fig. 114. Palmately-dissected leaf of the Yellow Water Ranunculus.

Fig. 115. Pinnately dissected leaf of Chamomile.

It not infrequently happens that the segments of a deeply indented leaf may again be incised, lobed, etc. Such forms, according to the depth of the incisions, and the arrangement of the segments, are described as *bipinnatifid*, *bipinnatisect*, *bipalmatisect*, etc.

Compound Leaves. A compound leaf is one whose blade is divided into two or more distinct subdivisions, called leaflets. These leaflets may possess stalks or *petiolules* of their own, and in many cases they are fastened to the main axis by means of a joint; but frequently also the leaflets are sessile, that is, attached directly to the main axis. In case, however, the parenchyma of the leaflet is confluent with the axis it is regarded as a divided simple leaf, and not as a compound one. It will be seen, therefore, that the transition from simple to compound leaves is a very gradual one. As a matter of fact, in some instances it is difficult to say whether a given form should be regarded as simple or as compound.

Since the compounding or branching of a leaf always follows the plan of venation, we may have either pinnately or radiately compound leaves.

The following are the most important of the pinnate forms:

The *pari-pinnate*, or abruptly pinnate, in which the leaf is terminated abruptly by a pair of leaflets, as in Fig. 116; the *im-*

pari-pinnate, or odd-pinnate, in which the leaf terminates with a single leaflet, as in Fig. 117; the *cirrhosely-pinnate*, in which the leaf is terminated by a tendril, as in Fig. 118; the *interruptedly-pinnate*, in which, as in the Silver-weed and Potato, Fig. 119, there are smaller leaflets scattered among larger ones; the *lyrate*, leaf, in which the terminal leaflet is largest, and the others successively smaller toward the base, as in Fig. 120, and the leaves that are more than once compounded on the pinnate plan. Fig. 121 shows a leaf which is twice compounded; it is called a *bi-pinnate* leaf; one which is three times compounded on the same plan is *tri-pinnate*; one that is many times pinnately compounded, *multi-pinnate*, etc., and a leaf which is somewhat irregularly compounded many times on the pinnate plan is termed *pinnately-decompound*.

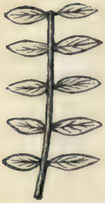


FIG. 116.

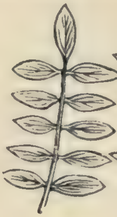


FIG. 117.

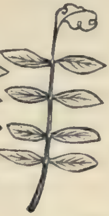


FIG. 118.

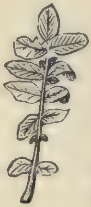


FIG. 119.

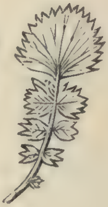


FIG. 120.

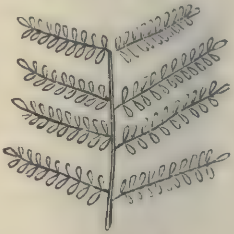


FIG. 121.

FIGS. 116 to 121, inclusive, forms of pinnately-compound leaves; 116, pari-pinnate; 117, impari-pinnate; 118, cirrhosely pinnate; 119, interruptedly-pinnate; 120, lyrate; and 121, bi-pinnate.

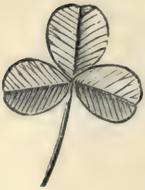


FIG. 122.

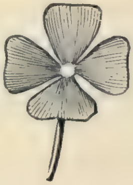


FIG. 123.

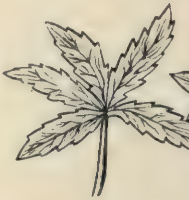


FIG. 124.

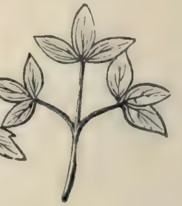


FIG. 125.

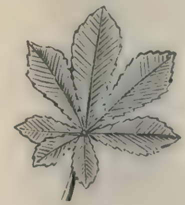


FIG. 126.

FIGS. 122 to 126, inclusive, forms of palmately-compound leaves; 122, ternate; 123, quadrate; 124, quinate; 125, bi-ternate; and 126, septenate.

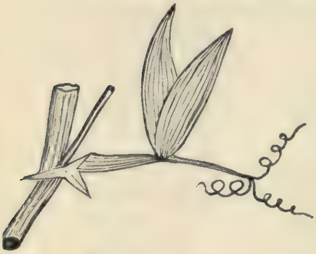
A similar series of terms apply to leaves compounded on the radiate plan. Such a leaf, compounded on the plan of three is a *palmately-trifoliolate* or *ternate* leaf, as the leaf of the Clover, Fig. 122; one with four radiating leaflets is *palmately-quadrifoliolate*, or *quadrate*, as the leaf of Marsilea, Fig. 123; a radiate leaf with five leaflets is *palmately-quinquefoliolate*, or *quinate*, Fig. 124, and the Horse-chestnut furnishes an example, Fig. 126, of a *palmately-septemfoliolate* or *septenate* leaf, while the Lupine and some other plants produce palmate leaves with a still larger number of leaflets. There are also *biternate*, *triternate*, *multiternate* and *ternately-decompound* leaves. Fig. 125 is an example of a bi-ternate leaf.

Leaf Surface. In the observation and description of leaves and other portions of the plant body, it is often important to take into account the character of the surface.

Plant surfaces are *glabrous*, when smooth, or free from hairs or protuberances of any kind ; *glaucous* or *pruinous*, when covered with a bloom, as the leaf of the Cabbage ; *punctate*, when dotted with pellucid or other dots ; *glandular*, when bearing glands or secreting vesicles on the surface ; *rugose*, when wrinkled ; *scabrous*, when harsh or rough to the touch ; *verrucose*, or verrucous, when covered with protuberances or warts ; *pubescent*, when covered with rather short, soft hairs ; *puberulent*, when minutely pubescent ; *sericeous*, when covered with a pubescence of very fine, appressed, silky hairs ; *lanuginous*, when covered with wooly hairs ; *tomentose*, or tomentous, when covered with matted or felted hairs ; *villose*, or villous, when bearing long, soft, shaggy hairs ; *pilose*, or pilous, when bearing long, straight, soft hairs ; *floccose*, or floccous, when bearing tufted, or cottony hairs ; *hispid*, when covered with stiff hairs or bristles ; *strigose*, or strigous, when covered with stout, sharp, appressed hairs ; *spinose*, or spinous when provided with spines ; *echinate*, when possessing barbed prickles ; and *aculeate*, when prickly

Texture of Leaves. It is also of some importance to observe the texture of leaves. They are described as *membranous*. when thin and pliable ; as *succulent*, when thickened and juicy, as the leaves of Live-for-ever, etc. ; as *scarious*, when dry, like bud-scales ; as *coriaceous*, when thickish and leathery, like the leaves of the great-flowered Magnolia ; as *herbaceous*, when green in color, as most ordinary leaves ; and as *petaloid*, when colored like petals, or of some lively color different from green.

Specially Modified Leaves. Some of these, such as bud-scales and leaf-tendrils, have already been mentioned, but there are many others which, having become adapted to functions altogether different from ordinary foliage, have also acquired forms which in some instances only remotely resemble those of foliage-leaves. The scales of bulbs like those of the Garlic and Lily, and of bulblets like those of some varieties of the Onion, are leaves surcharged with nutriment laid by to enable the plant to accomplish a vigorous growth during the succeeding season ; the spines into which some of the leaves of the Barberry and all of those of most species of Cactus are changed, subserve protective purposes, effectually defending the plants against browsing mammalia, and the upper leaflets of the common Pea and Vetch, Fig. 127, the entire blade and petiole of *Lathyrus aphaca*, Fig. 128, and the stipules of Smilax, Fig. 129, are modified into tendrils, and serve the purpose of climbing organs.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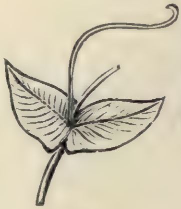
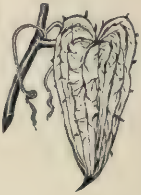


FIG. 128.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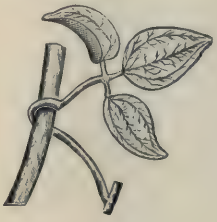


FIG. 130.

FIG. 127.—Leaf of Vetch with upper leaflets developed into tendrils.

FIG. 128.—Leaf of Lathyrus aphaca, with the leaf-blade and petiole developed into a tendril, while the functions of leaf-blade are discharged by the stipules.

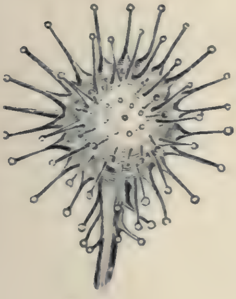
FIG. 129.—Leaf of Smilax, with the stipules developed into tendrils.

FIG. 130.—Leaf of a species of Clematis with petiole serving the function of a climbing organ.

Sometimes the petioles, while performing the ordinary function of supporting the blade, also become sensitive or irritable to the touch the same as tendrils, and like them perform the functions of climbing organs, as in the Clematis, Fig. 130, and Solanum jasminoides, already referred to, Fig. 18 ; and sometimes they are developed into insect traps of various forms, as in the Sundew, Dionæa, the various Pitcher-plants, etc.

Fig. 131 represents the leaf of the common Sundew. The hairs or tentacles distributed over the surface are each tipped with a pellucid drop of sticky material, by means of which small insects which alight on the leaf are secured ; the tentacles all then bend over upon the insect, and the leaf itself partially rolls inward so as to envelop him, and by means of a secretion akin to gastric juice, which the secreting glands of the tentacles pour out freely upon the doomed animal, the nutritive portions of his body are dissolved and gradually absorbed by the plant as food.

Fig. 132 represents one of the rosette of radical leaves of the Venus' Fly-trap, a plant belonging to the same family as the Sundew. The blade of the leaf consists of two spiny-margined valves, which are movable upon the mid-rib as upon a hinge. The face of each valve is also provided with three sensitive spines, and when an insect, attracted by the glandular secretions on the surface of the lobes, alights on one of them and touches one of the sensitive spines, the lobes instantly come together like the jaws of a steel-trap, almost invariably securing the intruder, which becomes the food of the plant, and is digested in much the same way as is done by the Sundew.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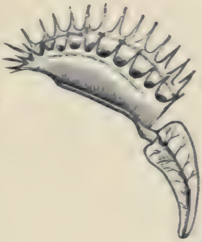
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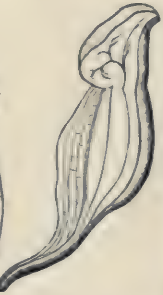
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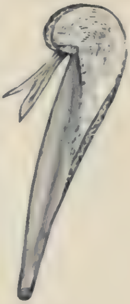


FIG. 134.

FIG. 131.—Leaf of the Sundew serving the purpose of an insect trap.
FIG. 132.—Leaf of Venus' Fly-trap.
FIG. 133.—Leaf of the Northern Pitcher-plant.
FIG. 134.—Leaf of the California Pitcher-plant (Darlingtonia).

The leaves of the Pitcher-plant of our northern bogs, Sarracenia purpurea, Fig. 133, also entraps insects, though in a quite different way, and uses them for food. The pitchers are usually found from half to two-thirds filled with water, which is mainly secreted by the plant; the lip of the pitcher has its inner surface clothed with stiff and sharp-pointed bristles, which point downward, and a secretion, enticing to insects, is poured out on the inner surface, particularly about the throat. Insects are thus enticed into the pitchers in great numbers, and owing partly to the difficulty of escaping past the sharp-pointed hairs, and partly, it is supposed, to the intoxicating effects of the secretion which they imbibe, they seldom escape, but are drowned in the water within the pitcher, and their decaying bodies form a rich manure which goes to sustain the life of the plant. The leaves of Darlingtonia, Fig. 134, a related plant of California, catch insects in much the same way, and make the same use of them. And the East Indian Pitcher-plant, Nepenthes, Fig. 135, has a leaf, the lower part of which serves as a blade, performing the proper functions of a foliage leaf; the middle portion is developed into a tendril, by means of which the plant climbs and the apical portion is developed into a pitcher which, like that of Sarracenia, entraps insects and utilizes them for food.

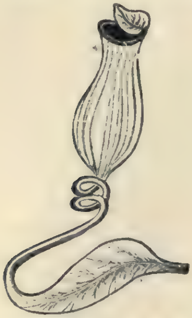


FIG. 135.—Leaf of the East Indian Pitcher-plant (Nepenthes).

There are several other plants also which possess insectivorous habits, and whose leaves are modified more or less with reference to these habits; among them are the Bladder-worts, which develop little, bladder-like crustacean traps on their leaves; the Pinguiculas, whose leaves are glandular on the upper surface, and which entrap and devour insects somewhat after the manner of the Sundew, though in a ruder fashion, and the Australian Cephalotus, which bears among its ordinary leaves others in the form of very perfect pitchers.

PRACTICAL EXERCISES.

1. Compare the following leaf forms and note their resemblances and differences: The scales of a Hickory bud, the fleshy scales of a Lily bulb, the large spines on the Prickly-pear Cactus, the different forms of leaves on the Barberry, the leaves of the Pitcher-plant, the petals of the Rose, and the leaf of the Maple.

2. Determine what organs are represented, respectively, by the tendrils of the Grape, the thorn of the Plum, the flattened joints of the Prickly-pear Cactus, and the pod of the Pea.

3. Describe the following simple leaves as to their venation, the parts present, general outline, apex, base, margin, surface and texture, using the correct botanical terms: Those of the White Oak, Stramonium, Hard Maple, Birch, House Ivy, Solomon's Seal Onion, White Pine, Timothy Grass, and Live-for-ever.

4. Describe the following compound leaves as to the parts present, the plan of compounding, the number of leaflets and the general outline, apex,

base, margin, surface and texture of the leaflets, using the descriptive language of botany: Those of the Pea, the Hemp, Sweet Clover, Common Field-Clover, Meadow-Rue, Locust, Honey-Locust, and Ash.

5. Describe the Phyllotaxy of the Locust, of the Sycamore, of the Crab-Apple, of the Common Milk-Weed, of the Elm, of the Canada Lily, of the Flax, and of the White Pine.

6. Examine the buds or unfolding leaves of the following plants and determine the vernation: The Hickory, the Custard Apple, the Sweet Flag, the House Geranium, the Oak, the Sycamore, the Plantain, the Maple, the Common Polypody and the Ash.

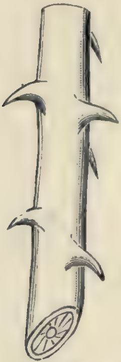
CHAPTER IV.—PLANT-HAIRS OR TRICHOMES.

Though these organs are, for the most part, minute and simple in their structure, we are justified, on account of the important functions which many of them perform, in classing them as distinct organs of vegetation. They are, for the most part, appendages to the epidermis; sometimes, however, they include tissues of the hypoderma, and rarely, as in the glandular hairs of the Sundew, they are quite complex structures, and contain vascular tissues. They may be borne by any other organ of the plant, that is, by root, stem or leaves, and they usually occur without definite order. In rare instances, organs which we must regard as hairs, occur in interior tissues, particularly in some aquatic plants, like the Water-lilies, that have large inter-cellular spaces or air channels in their stems and leaves. In such cases they are located in the tissues adjacent to the inter-cellular spaces, and project into the latter as other hairs do into the open air. These internal hairs are called *trichoblasts.* (See Vegetable Histology).

The primary function of hairs appears to be that of absorbing nourishment. How important root hairs are in this respect has already been stated, but they are not the only ones that perform this function. The uses of the glandular hairs of Sundew and other insectivorous plants have just been mentioned, but it is also known that the hairs on the stems and leaves of the Chinese Primrose, the House Geranium (Fig. 155), and some species of Saxifrage, are active agents in absorbing nitrogenous compounds from the air, and there is good reason to believe that in many other plants they perform similar important services.

The absorption of nutriment, however, is not their only use. Like the other organs studied, they have frequently become modified and adapted for uses quite different from the normal, and like them, also, in some instances, they exist merely as abortive and functionless organs.

One important use, different from the normal, which many of them subserve, is that of protection. To this end they are variously modified in form and structure. In the Opuntia Cactus, Fig. 162, they become hardened, sharpened and barbed, and in the western Mentzelia ornata, Figs. 163, 164 and 165, are barbed and strongly silicified, so that, if animals feed upon either of these plants, their lips and tongues will be so painfully irritated that they will not be likely to repeat the experience. In the Blackberry, Greenbrier, Gooseberry and Rose, Fig. 138, some of the hairs develop into hard, sharp prickles, which cause herbivorous animals to avoid them. In the Nettle and Wigandia urens they are modified into still more efficient protecting organs, namely, stinging-hairs, which consist of slender, rigid tubes, swollen at their base into a flexible-walled sac filled with an irritant fluid. These hairs are so constructed that, when touched by an animal, their tips, which are very fragile, are liable to be broken off, and the sharp, tubular shafts driven into the skin, at the same time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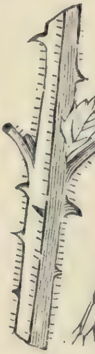
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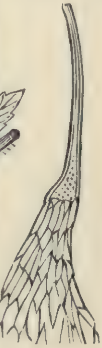
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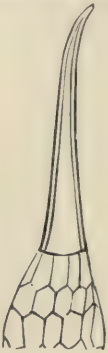
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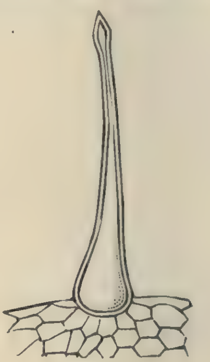


FIG. 142.

FIG. 138.—Portion of Rose stem showing recurved prickles.
FIG. 139.—Portion of stem of Lantana, showing hooked prickles, ordinary hairs and glandular hairs.
FIG. 140.—Young prickle of Lantana, enlarged, showing how, in this case, the prickle is formed by the development of the papilla at the base of an ordinary hair.
FIG. 141.—Stinging hair of a species of Nettle, magnified.
FIG. 142.—Stinging hair of Wigandia urens, magnified.

producing pressure upon the poison sacs at the base and injecting the irritant liquid into the wound (see Figs. 141 and 142). The glandular hairs of the Tobacco, and of the Sage, Fig. 143, the bristly hairs of the Canada Fleabane, the stellate hairs of Solanum elæagnæfolium, Figs. 156 and 157, and of related western species, the branching, glutinous hairs of the common Mullein, Fig. 154, and doubtless the dense, hairy coverings of many other plants, efficiently protect them from the ravages of many destructive insects. It is reasonable to suppose, also, that the dense covering of hairs often found on the under surface of leaves, may, besides guarding these very vulnerable parts of the plant's surface from insect enemies, serve to prevent dust particles from lodging upon and clogging the stomata, and, what is of much greater importance, protect them from the spores of destructive fungi, which otherwise would often find a lodgment in the stomata, and germinating, penetrate the leaf, destroying its tissues and endangering the life of the plant. This view is the more probable since we know that many of the more destructive moulds have no power to penetrate the leaf except through the stomata.

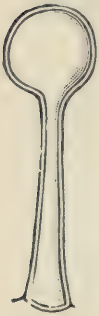
In connection with the protective influence of hairs, it is significant that the young and tender leaves of many plants are well covered with glandular, or other hairs, while the mature leaves of the same plant are entirely free from them. Some species of Oak, Hickory and Rhododendron afford examples. In the latter plant, the young leaves are very glutinous from the presence of club-shaped, many-celled glandular hairs, one of which is illustrated in Fig. 158. The mature leaves do not possess them.

In some species of Thistles and other Compositæ, the glandular hairs borne on the involucre, and on the stalk of the inflorescence below it, are serviceable in preventing ants and other wingless insects from gaining access to the flowers and robbing them of their sweets and so preventing the visits of winged insects that would be useful in transferring the pollen from one flower to another, and so effecting cross-fertilization, a matter of no little importance to plants, as we shall hereafter see. The glandular secretions on the upper internodes of the Catch-fly perform a similar service.

Hairs are also useful in aiding the dispersion of some seeds and fruits. The seeds of the Cotton-plant, the Milkweed, the Dogbane and the Willow-herb, are rendered buoyant by them, so that they are readily scattered by the wind. The fruits of the Desmodiums and of Circæa Lutetiana are covered with hooked hairs (see Fig. 146), by means of which they cling to the fleece of animals and are thus scattered.

The dense hairy clothing so noticeable on many plants inhabiting dry, arid regions, may serve to temper the energy of the sun's rays by day, and also prevent the excessive radiation of heat from the plant and the chilling of its tissues at night.

In Ferns and some other flowerless plants, hairs undergo a still more important modification, namely, some of them are developed into sporangia or spore-cases, thus subserving the important function of reproduction.



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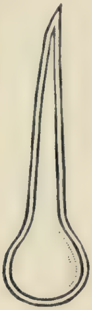
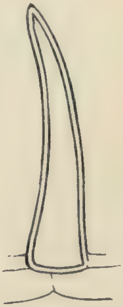


FIG. 144.



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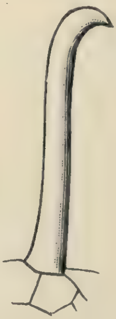

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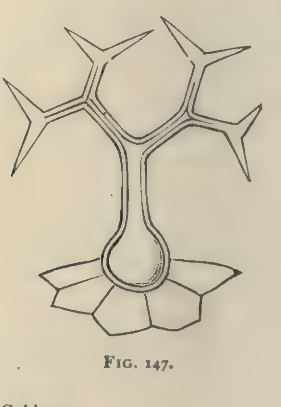
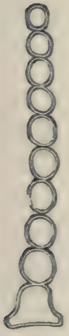


FIG. 147.

FIG. 143.—Unicellular, grandular hair of Sage.
FIG. 144.—Simple unicellular hair from the leaf of the Cabbage.
FIG. 145.—Unicellular hair of the Evening Primrose.
FIG. 146.—Hooked hair from the fruit of Circæa Lutetiana.
FIG. 147.—Branching unicellular hair of one of the Cruciferæ. All magnified.

Classification of Hairs.—Hairs may conveniently be classified into *unicellular* and *multicellular* forms. The unicellular kinds may be simple, as in Figs. 143, 144 and 145, or they may be branching, as in Figs. 147 and 166. The multicellular forms may consist of a single row of cells placed end to end, as in the moniliform hairs of Tradescantia, Fig. 148, and of Mirabilis Jalapa, Fig. 150; or they may consist of cells which lie in a single plane, as the flattened hairs called chaff that occur on many Ferns, Fig. 159, and the stellate hairs of Shepherdia, Fig. 152; or, as in most prickles, the hairs of Sundew and of Rhododendron, Fig. 158, they may consist of solid masses of cells. Multicellular hairs may also be simple, as in the Squash, Fig. 153, or branching as in the Mullein, Fig. 154. Hairs, as we have seen, not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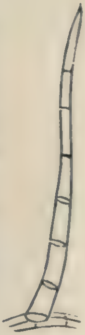
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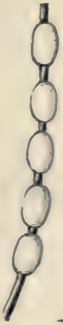
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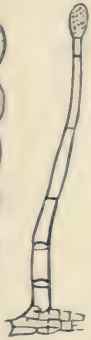
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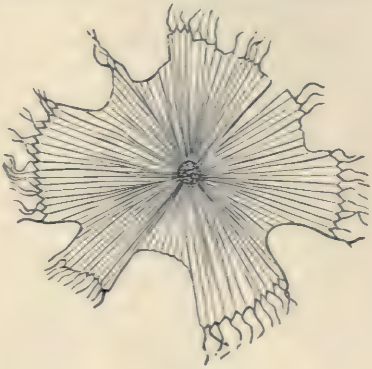
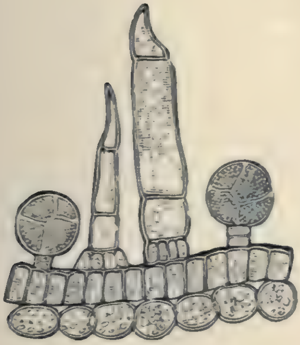


FIG. 152.

FIG. 148.—Moniliform hair from the stamen of Tradescantia.
FIG. 149.—Simple multicellular hair from the leaf of Ageratum.
FIG. 150.—Moniliform hair of Mirabilis Jalapa.
FIG. 151.—Multicellular hair, having a gland at its tip, from the stem of Petunia.
FIG. 152.—Flattened hair from the leaf of Shepherdia Canadensis. All magnified.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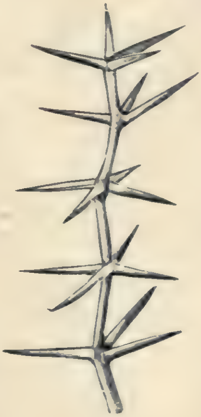
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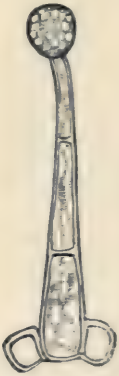
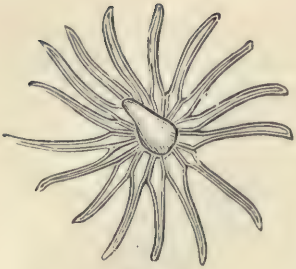


FIG. 155.

FIG. 153.—Different forms of hairs found on the stem of the Squash.
FIG. 154.—Branching multicellular hair of Mullein.
FIG. 155.—Multicellular glandular hair from the stem of the house Geranium. All magnified.



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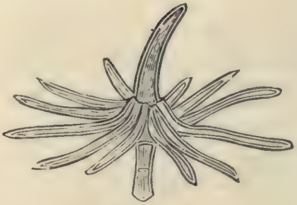

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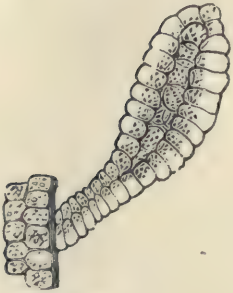


FIG. 158.

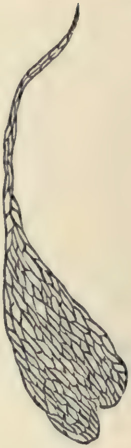
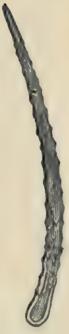


FIG. 159.



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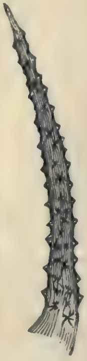


FIG. 161.

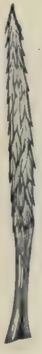


FIG. 162.

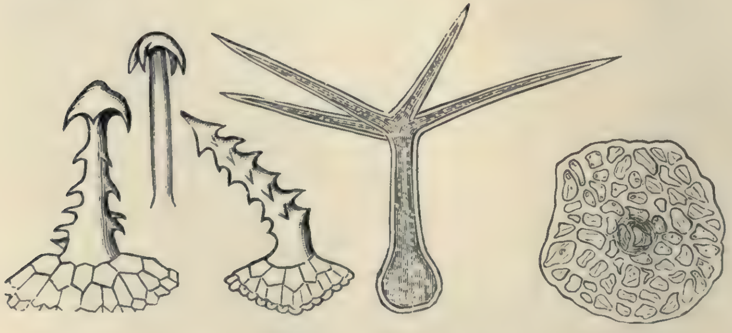


FIG. 163. FIG. 164. FIG. 165. FIG. 166. FIG. 167.

FIGS. 156 and 157.—Top and side views respectively of hair of Solanum elæagnifolium, magnified about 100 diameters.

FIG 158.—Multicellular, glandular hair of Rhododendron, magnified about 185 diameters.

FIG. 159.—Flattened multicellular hair of a species of Shield-fern, magnified about 25 diameters.

FIGS. 160 and 161.—Verrucose hairs from leaves of Heliotropum tenellum and Heliotropum convolvulaceum, the former magnified 75, the latter 25 diameters.

FIG. 162.—Barbed hair of Opuntia Rafinesquii, magnified about 20 diameters.

FIGS. 163, 164 and 165.—Different kinds of barbed hairs from leaf of Mentzelia ornata.

FIG. 166.—Branching unicellular hair of Draba Caroliniana, magnified about 100 diameters.

FIG. 167.—Peltate hair of Cassandra calyculata, magnified about 185 diameters.

infrequently secrete a glutinous or odorous secretion. Such hairs are called *grandular.* They also may be unicellular, as in the Sage, Fig. 143, or multicellular, as in the House Geranium, Fig. 155. Other forms of hairs are represented in Figs. 161 and 162, and 167, which represent respectively hairs of Heliotropum tenellum, Heliotropum convolvulaceum, and Cassandra calyculata.

PRACTICAL EXERCISES.

By means of your magnifying lens examine the following plants, or parts of plants, and describe and draw the shapes of the hairs: The Garden Verbena, or one of the wild Vervains; the garden Aster; the young leaves and branches of the house Ivy; the stems and leaves of Erigeron Canadense; the leaves of the common Mullein; the prickles of the Raspberry and Blackberry; the scales or chaff on the stipes of Aspidium marginale; the young leaves of the Hickory and Walnut; the leaves and flower-heads of the Pasture Thistle; the young leaves of the Common Hazel and of the Witch hazel; the under surfaces of the leaves of Shepherdia; the leaves of Spanish Moss, and the spore-cases on the leaves of the common Polypodium. Ascertain the probable functions of the hairs in each instance, and state your conclusions.

CHAPTER V.—THE BRANCHING OF ORGANS.

Any organ of the plant-body may branch, and the branching is always according to one or other of two general types, the *Dichotomous* or the *Monopodial.* In the former mode the branching takes place by forking, or by the repeated division of the apex of the organ into two equal portions, as illustrated in Fig. 144. Three different varieties of this mode are observed.

(1) The *Forked Dichotomy*, in which the branches develop equally, as in Fig. 169;

(2) The *Helicoid Dichotomy*, in which the branch on one side is invariably suppressed, or less strongly developed than the other, as illustrated in Fig. 170; and

(3) The *Scorpioid Dichotomy*, in which a branch is suppressed, or but partially developed, first on one side and then on the other, as in Fig. 171.

This plan and its various modifications are more commonly seen in flowerless than in flowering plants. It is the common mode of branching in Marine Algæ, the leaves of some Ferns and in the stems and roots of Club-Mosses.

In the monopodial type the branches originate as lateral outgrowths, back of the apex of the main stem, as illustrated in Fig. 172. There are also several modifications of this type :

(1) The *Racemose Monopodium*, in which the main axis retains the ascendancy over its branches, as in Fig. 172.

(2) The *Cymose Monopodium*, in which the main axis is soon suppressed and the lateral branches gain the ascendancy. Of the latter kind there are several variations :

(a) The *False Dichotomy*, represented in Fig. 173, in which the lateral branches develop in such a manner as to resemble true forks, or a genuine dichotomy.

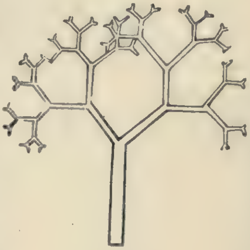


FIG. 169.

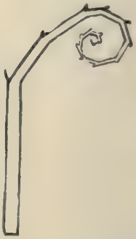


FIG. 170.

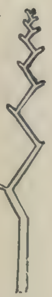


FIG. 171.

FIG. 169 —Diagram of forked dichotomy.
FIG. 170.—Diagram of helicoid dichotomy.
FIG. 171.—Diagram of scorpioid dichotomy.

(b) The *Helicoid Monopodium*, in which the main axis and lateral branches on one side are habitually suppressed, while the branches on the other side are developed to form a false axis, as in Fig. 174.

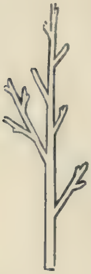


FIG. 172.

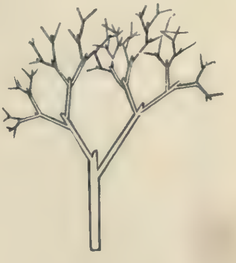


FIG. 173.

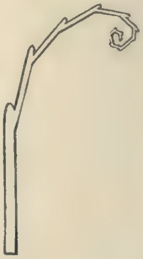


FIG. 174.

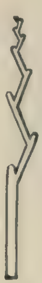


FIG. 175.

FIG. 172.—Diagram of a racemose monopodium.
FIG. 173.—Diagram of false dichotomy.
FIG. 174.—Diagram of the helicoid monopodium.
FIG. 175.—Diagram of the scorpioid monopodium.

(c) The *Scorpioid Monopodium*, in which the main axis soon ceases to grow and the branches are suppressed alternately on one side and then on the other, as illustrated in Fig. 175.

The monopodial type of branching is the one seen in the stems of Mosses, in both the roots and stems of Equisetums, in the roots, and sometimes in the leaves of Ferns, and in the stems, roots and leaves of nearly all flowering plants.

PRACTICAL EXERCISES.

Study carefully, as examples of the various modes of branching, the following, making diagrams of each: (1) The common Liverwort, Marchantia polymorpha, as an illustration of forked dichotomy; (2) the larger branches of the common Maidenhair Fern, Adiantum pedatum, as illustrating helicoid dichotomy; (3) the smaller branches of the same plant, as illustrative of Scorpioid dichotomy; (4) the trunk and branches of the Balsam Fir, as illustrating a racemose Monopodium; (5) the branching of the Lilac and Mistletoe, as illustrating the false dichotomy; (6) the arrangement of the flower clusters of the common Day Lily, as illustrative of the helicoid Monopodium, and (7) the flower clusters of the Sundew, as typical of the scorpioid Monopodium.

The student should bear in mind that while in these examples the different modes of branching are clearly illustrated, it is not always equally easy to determine the plan, but sometimes a careful microscopical study of the branches in an early stage of their development is necessary.

THE ORGANS OF REPRODUCTION.

INTRODUCTORY.—NATURE OF THE FLOWER.

The organs of reproduction in phænogamous or flowering plants consist of *flower*, *fruit* and *seed*. They constitute a mechanism, more or less complex, whose function it is to continue the species. To this end, each part of the mechanism is subservient, and each, therefore, has a meaning which we should endeavor to understand. No part of it is so minute or apparently insignificant as not to deserve careful attention and thorough study. The organs of reproduction are not only interesting in themselves, for flowers, particularly, make strong appeals to everyone's sense of the beautiful, and inevitably awaken in thinking minds a desire to understand their structure, but they also furnish us with the most reliable characters for determining how nearly or how remotely, different plants are related to each other ; in other words, for classifying them according to their natural relationships.

Perhaps nothing in the vegetable world is more wonderful than the immense variety of flowers. But this multiplicity of forms has not always existed. A careful study of the flora of the past, as revealed in its fossil forms, and a discriminating study of the plants of our own time, necessitates the conclusion that all this variety and complexity have arisen from comparatively few and simple forms. Progressive adaptation to environment has been the law of vegetable life. Plants have been subject to changing conditions of soil and climate. The earth's crust has been slowly elevated in some localities, and depressed in others ; large areas of land have been alternately raised above the sea level and then submerged ; these things have necessitated profound changes in temperature, in atmospheric humidity, and in other conditions affecting plant growth. Moreover, plants maintain a continual struggle with each other for the occupancy of the soil—a struggle whose conditions vary, not only with the changing physical conditions in the same locality, but with the dispersal of plants by various natural agencies to new localities, bringing them into association with new plants and with new animal friends and foes. All these changes, necessitating changes in the habits of plants, taken in connection with the well-known tendency of plants to vary, have led to profound modifications in their structure. The descendants of plants which were alike, have come to differ from each other and from the parental forms; from a few kinds, an immense number of species and varieties have arisen.

In the course of the adaptive changes which plants have undergone, the organs of reproduction have, of course, also undergone much modification; but here conservatism is more evident, especially as respects the essential organs of the flower, and changes in them have taken place more gradually than in other parts of the plant. The habits and appearance of related plants may have undergone profound change, while the flowers still bear a strong resemblance to each other in essential points of structure. The Elm and the Nettle, for example, are as different as possible from each other in size and in habits of growth, yet the record of their close relationship is preserved in their flowers.

It is for these reasons—because of the light which flowers throw on the relationships of plants, and the clews they give us to the history of their descent—even more than on account of the appeal which beautiful flowers make to the æsthetic sense, that they command the enthusiastic interest of botanists.

It must not be inferred from this, however, that the scientific study of a flower in any way dulls the enjoyment of it as a thing of beauty. It is a foolish, though very popular, error to suppose that this is the case. It would be scarcely less absurd to suppose that the less one knows of art, the more he will enjoy a fine picture or a fine statue. Surely, in the study of flowers, as in every other worthy subject of knowledge, our enjoyment of them will increase as we understand them, and it will be measured by the extent and thoroughness of our knowledge of them.

But we must guard against the error of supposing that in studying the organs of reproduction, we are studying entirely new ones. They are, in fact, the old vegetative organs, changed for the purpose of adapting them to new functions. The "leaves of the flower" (petals and sepals) are really leaves, in the great majority of cases, but leaves adapted to new uses; instead of elaborating food for the plant, as is the case with ordinary foliage, they subserve the functions of reproduction. Stamens, also, and pistils, though they do not usually bear the remotest resemblance to ordinary leaves, are really modified forms of them. The fruit, too, is a modified leaf or cluster of leaves, or sometimes of stem and leaves united, and the seed is an appendage to, or an outgrowth from, a leaf. That this is the real nature of the floral organs is shown, *first*, by the fact that they occur on the stem in the same order as leaves, and develop from it in the same way; *second*, from the fact, that in the earliest stages of their growth, they are indistinguishable from true leaves in the corresponding stage of development; *third*, by the fact, that sometimes, when mature, they present every gradation from ordinary foliage, through bracts and sepals to petals and stamens; and *fourth*, from the fact that many instances are known of abnormal or monstrous flowers, where some or all of the floral organs have reverted, more or less completely, to the condition of ordinary green leaves.

Nature of the Flower. *A flower really consists, then, of a short branch or stem on which leaves, modified for the purposes of reproduction, are compactly arranged.* Nature, requiring of it other uses than those of ordinary vegetative growth, has changed the form, and commonly also, the color of its parts, suiting these to the requirements of the reproductive process. Its leaves, for the most part, except the outer whorl, have entirely ceased to perform vegetative functions, and are devoted solely to the new work. Each different kind of floral leaf has also become adapted to the particular work required of it, the petals and sepals doing a different duty from that of the stamens, and the latter, in turn, a different one from that of the pistils, but all contributing to the important end of producing the seed. For this the flower exists. To this object its entire mechanism, and even the beauty of its corolla, its perfume and its nectar, are subservient. Even the vegetative processes of the plant, which precede the flowering, have largely for their object the storage of the energy necessary to enable the plant to produce its flower and develop its seed. The life of the plant, therefore, culminates in its flower; it reaches its perfection as a plant then, and in many cases, from that time ceases its growth. During its formation and the subsequent process of perfecting the seed, its stored-up energies suffer heavy drainage, resulting either in the death of the plant, as in the case of annuals, biennials and some perennials, or in its entering upon a period of rest to recuperate its exhausted vitality.

Let us begin our study of flowers by observing their anthotaxy.

CHAPTER VI.—ANTHOTAXY.

By Anthotaxy is meant *the arrangement of the flowers on the stem.* It is often called inflorescence. Flowers may occur singly on the stem, or in clusters, and the latter may have various shapes and characteristic modes of arrangement.

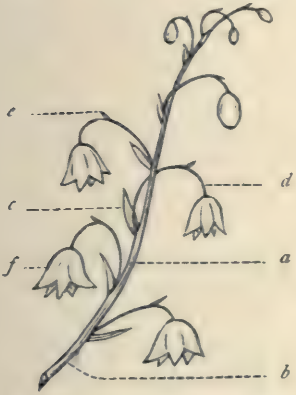


FIG. 176.—A raceme, showing axis of inflorescence, or rachis, *a*; common peduncle, *b*; pedicels, *d*; bracts, *c*; bractlets, *e*; and flowers, *f*.

In a flower-cluster, the axis along which the flowers are arranged is called the *rachis*, or axis of inflorescence; the common stalk of the cluster, the *common peduncle;* the stalks of the individual flowers, the *pedicels;* and the modified leaves from which the branches of the cluster spring, *bracts* or *bractlets*, according as they occur on the rachis or on some of its branches. See Fig. 176 and accompanying explanation.

There are two distinct types of Anthotaxy, the *indeterminate* or axillary, and the *determinate* or cymose.

An *Indeterminate Anthotaxy* is one in which the flowers occur in succession from the base toward the apex of the main stem. When clustered on this plan, those flowers come into blossom first which are situated lowest down on the rachis, or, in the case of a flat-topped cluster, at the periphery. The principal forms of this type are the following:

(1) The *Solitary Indeterminate* is one in which the flowers occur singly in the axils of ordinary leaves, as in the common Pimpernel, Fig. 177.

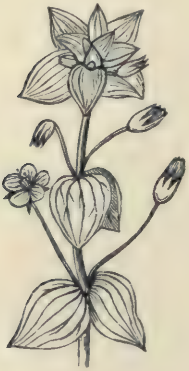


FIG. 177.

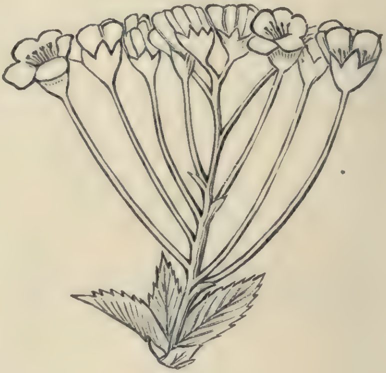


FIG. 178.

FIG. 177.—Pimpernel, showing solitary indeterminate inflorescence.
FIG. 178.—Corymb of a species of Cherry.

(2) The *Raceme* is a cluster in which the flowers are pedicelled and occur in succession along a lengthened axis, blossoming from the base toward the apex, as in Fig. 176. Examples occur in the Choke-cherry and in the Currant.

(3) The *Corymb* is like a raceme, except that it has the rachis proportionately shorter, and the lower pedicels somewhat lengthened so as to bring all the flowers to about the same level, as in Fig. 178, which represents the inflorescence of another species of Cherry.

(4) The *Umbel* resembles a raceme, but has the rachis reduced still more than in the corymb, and the nearly equal pedicils radiate from it like the rays of an umbrella, as in some species of Onion, Fig. 179.

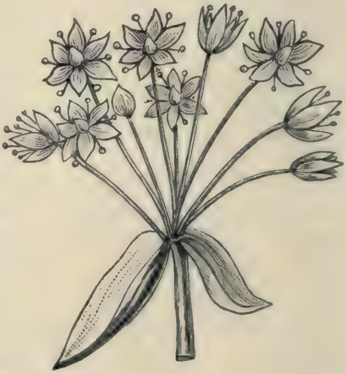


FIG. 179.—Umbel of a species of Onion.

(5) The *Spike* is like a raceme, except that the flowers are

sessile instead of pedicelled. Examples occur in the wild Vervains and in the common door-yard Plantain, Fig. 180.

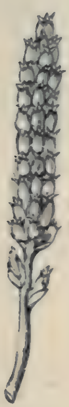


Fig. 180.

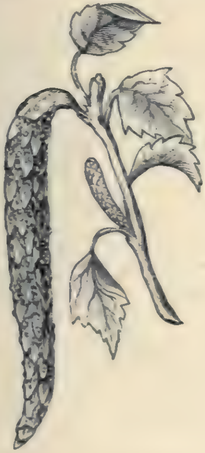


Fig. 181.

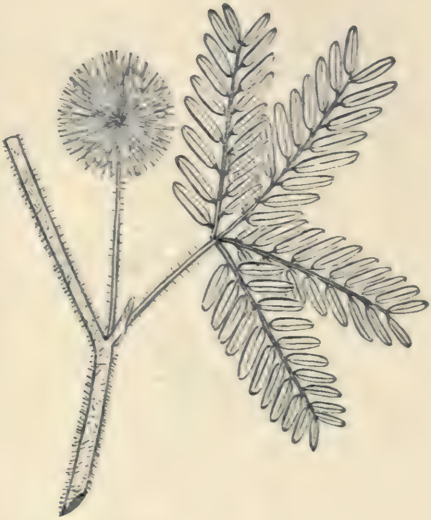


Fig. 182.

Fig. 180.—Spike of Plantain.
Fig. 181.—Catkin of Birch.
Fig. 182.—Head of Mimosa pudica.

(6) The *Catkin*, or *Ament*, is similar to the Spike, having its flowers sessile along a lengthened axis, but it differs from the latter in the fact that it has scaly instead of herbaceous bracts, as the clusters of staminate flowers of the Oak, Chestnut, Hazel and Birch, Fig. 181.

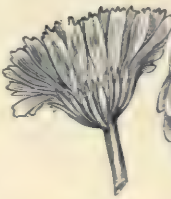


Fig. 183.

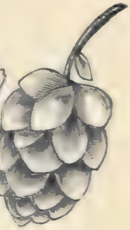


Fig. 184.

Fig. 183.—Head of Marigold.
Fig. 184.—Strobile of Hop.

(7) The *Head* or *Capitulum*, is like a Spike, except that it has the rachis shortened so as to form a very compact cluster of sessile, or nearly sessile, flowers, as in the Clover, Dandelion, Button-bush, Mimosa, Fig. 182, and Marigold, Fig. 183.

(8) The *Strobile* is a compact cluster with large scales concealing the flowers, as the inflorescence of the Hop, Fig. 184.

(9) The *Spadix* is a flower-cluster like a spike (or sometimes shortened into a head) that is partially or wholly enclosed in a

large bract called a spathe, which springs from its base. The inflorescence of the common Calla, the Skunk-cabbage and the Indian-turnip, Fig. 185, are illustrations.

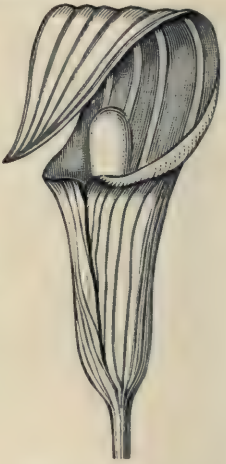


FIG. 185.—Spadix of Indian-turnip.

Several of the forms above described may be more or less compounded. For example, there are *compound racemes*, *compound corymbs*, *compound umbels*, and *compound* or *panicled spikes*. The compound raceme, particularly if it is somewhat irregularly compounded, is commonly called a *panicle*, as in the Yucca, Fig. 186. Fig. 187 illustrates the compound umbel of Fennel, and Fig. 188, the panicled spikelets of the Oat.

The bracts which subtend the heads of the Compositæ, and those which occur in whorls at the base of other compact flower-clusters, as the umbels of many Umbelliferæ, as well as the whorl of bracts which sometimes occurs beneath a single flower, as in the Anemone, are termed the *involucre*. See Fig. 183.

A *Determinate Anthotaxy* is one in which the first flower that opens is the terminal one on the rachis, and the others appear in succession from the apex toward the base. In case the cluster on this plan

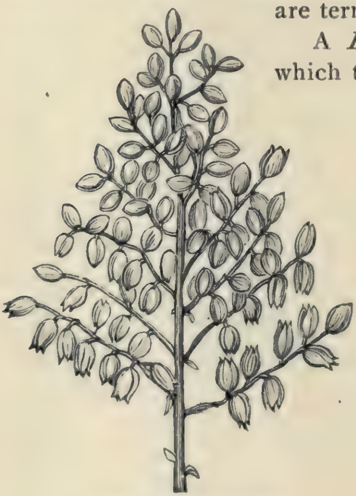


FIG. 186.—Panicle of Yucca.

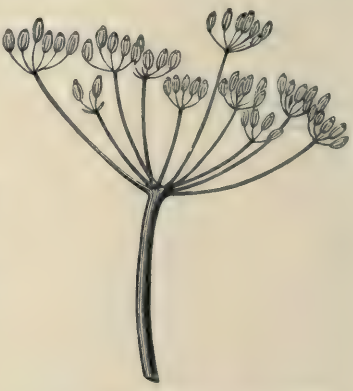


FIG. 187.—Compound umbel of Fennel.

is flat-topped, the flowering begins at the centre instead of at the periphery, consequently the inflorescence is often described as *centrifugal*, in distinction from the indeterminate form, which is described as *centripetal.*

The principal varieties of determinate anthotaxy are the following:

(1) The *Solitary Determinate* is one in which there is a single flower at the end of the stem, as in the Wood Anemone, Fig. 189.

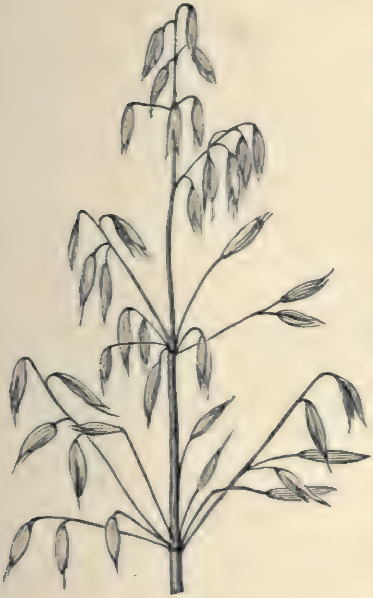


FIG. 188.

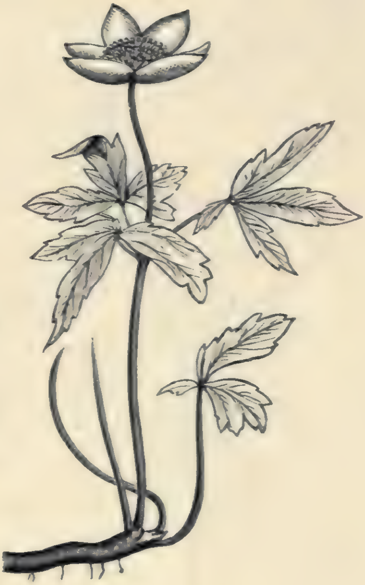


FIG. 189.

FIG. 188.—Panicled spikelets of the Oat.
FIG. 189.—The Wood Anemone, illustrating solitary determinate inflorescence.

(2) The *Cyme* is a loose cluster on the determinate plan, such as that illustrated in Fig. 190, which represents the inflorescence of a species of Cerastium. A diffuse and freely branching cyme, like that of the common Elder and the Viburnums, is frequently called a *Compound Cyme*, and when such a cyme has shortened pedicels and is compactly arranged, as in the inflorescence of the garden Sweet William, it is termed a *Fasicle.*

(3) A *Glomerule* or *glomerulus*, is a dense cluster on the

cymose plan, whose flowers are sessile, or nearly so, on a short rachis. It resembles a head, but differs from it in the fact that the inflorescence is centrifugal. The Flowering and Canada Dogwoods both illustrate this form of inflorescence. See Fig. 191. The flower-cluster, as will be seen, is subtended by four conspicuous bracts, constituting an involucre; *a* represents one of the florets of the cluster magnified.

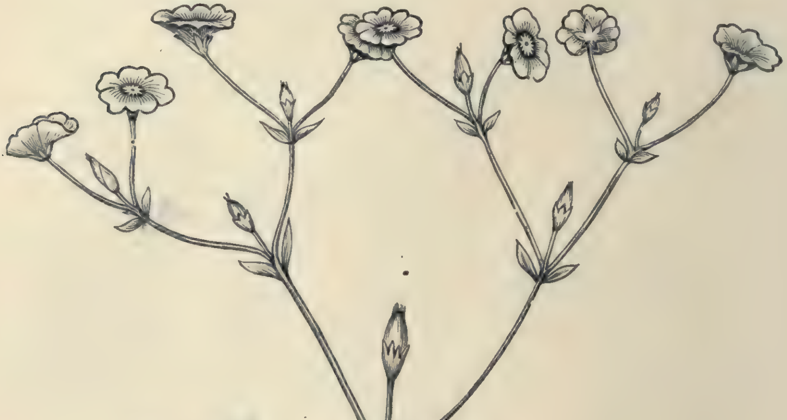


Fig. 190.

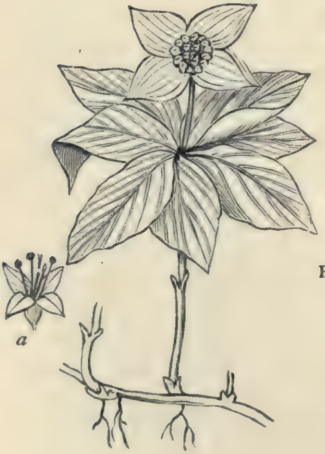


Fig. 191.

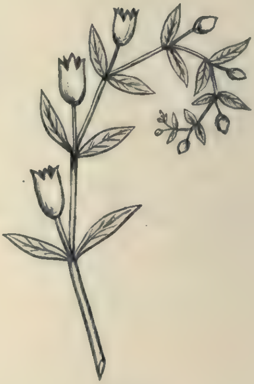


Fig. 192.

Fig. 190.—Open cyme of a species of Cerastium.
Fig. 191.—Glomerule of the Canada Dogwood.
Fig. 192.—Diagram of Scorpioid Cyme.

A *Scorpioid Cyme* is one that imitates a raceme in appearance, having the flowers pedicelled and arranged along a lengthened axis. As in the raceme, the basal flower of the cluster is the oldest, but it is in reality terminal instead of axillary, as shown in the diagram, Fig. 192. Such an inflorescence arises either from the suppression of all the branches on one side, in which case it would properly be called helicoid, or from the alternate suppression of branches, first on one side and then on the other, when it would be, in the strict sense, scorpioid. Owing, however, to the difficulty of distinguishing the two varieties when mature, they are indiscriminately called scorpioid cymes. Such cymes are commonly one-sided or coiled in form. They are illustrated in the Sundew, the Heliotrope and the Forget-me-not, Fig. 193. Cymes of this kind also, not uncommomly branch into compound forms.

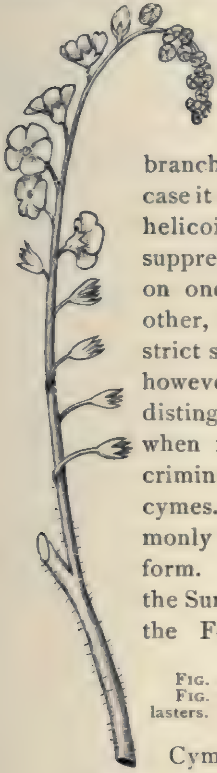


FIG. 193.

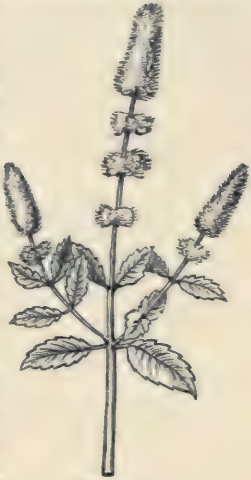


FIG. 194.

FIG. 193.—Scorpioid Cyme, or false raceme of Forget-me-not.

FIG. 194.—Inflorescence of Peppermint, illustrating spiked verticillasters.

(5) A *Verticillaster* is a compact cymose flower-cluster, which at first sight appears like a whorl or circle of flowers about a stem, but which in reality consists of two glomerules situated in the axils of opposite leaves. Clusters of this kind are seen in the Catnip, Hoarhound, Peppermint and other plants belonging to the natural order Labiatæ, Fig. 194.

A *Mixed Anthotaxy* is one in which the indeterminate and determinate plans are combined. Illustrations of this kind occur in many of the Compositæ where the heads of flowers, which of course are indeterminate clusters, are arranged in cymes. In the mints, on the contrary, verticillasters or cymose clusters are often arranged in spikes, as seen in the Peppermint, Fig. 194.

Mixed panicles are of very common occurrence, in fact more common than the purely indeterminate forms. They may be of two kinds, either the primary ramifications may be indeterminate and the secondary or ultimate ones determinate, or the latter may be indeterminate while the former are determinate. A somewhat elongated, profusely branching and compact cluster of the former sort, like the inflorescence of the Lilac and Horse-chestnut, is commonly called a *thyrsus* or thyrse.

RECAPITULATION.

- Anthotaxy or Inflorescence.
  - Indeterminate or Indefinite.
    - Solitary.
    - Raceme
    - Corymb.
    - Umbel.
    - Spike.
    - Catkin or Ament.
    - Capitulum or Head.
    - Strobile.
    - Spadix.
    - Compound Raceme, Corymb, Umbel, etc.
  - Determinate or Cymose.
    - Solitary.
    - Cyme (proper).
    - Compound Cyme.
    - Fasicle.
    - Glomerule.
    - Scorpioid Cyme.
    - Verticillaster.
  - Mixed.
    - Mixed Panicle.
    - Thyrsus or Thyrse.
    - Spiked Verticillaster, etc.

PRACTICAL EXERCISES.

Determine whether the following inflorescences are indeterminate, determinate or mixed, and give the particular names applicable to each: The Currant, the Carrot, the Mustard, the Sycamore, the Red-ozier Dogwood, the Willow, the Frost Grape, the Wheat, the Potato, the common Milk-weed, the Hydrangea, the Burdock and the Harebell.

CHAPTER VII.—PREFLORATION OR ÆSTIVATION.

By prefloration or æstivation is meant the arrangement of the floral organs, particularly calyx and corolla, in the bud. Since the parts of flowers are modified leaves, and flower-buds are structurally similar to leaf-buds, it is not strange that most of the terms explained under the head of prefoliation or vernation are applicable also to the arrangement of the floral organs in the bud. These terms need not again be defined, but a few additional forms will be described, all of them relating to the arrangement of the organs with reference to each other.

1. The *Valvate Prefloration.* In this, the margins of adjacent members are contiguous merely, that is, do not at all overlap in the bud. It is seen in its simplest form in the calyx of the Basswood flower, a ground plan of which is shown in Fig. 195. Of this form there are three other modifications: the *induplicate-valvate,* in which the edges of contiguous organs are bent inward, as in Fig. 196; the *reduplicate-valvate,* in which the edges are bent outward, as in Fig. 197; and the *involute-valvate,* in which the edges are rolled inward, Fig. 198.

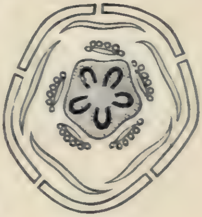


Fig. 195.

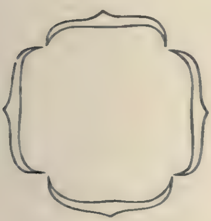


Fig. 196.

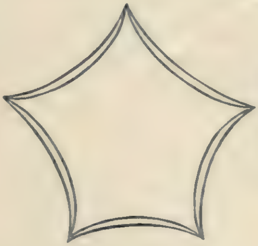


Fig. 197.

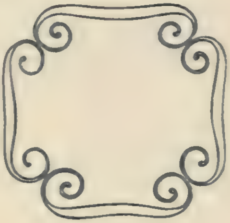


Fig. 198.

Fig. 195.—Ground plan of flower of common Basswood.
Fig. 196.—Diagram of induplicate-valvate prefloration.
Fig. 197.—Diagram of reduplicate-valvate prefloration.
Fig. 198.—Diagram of involute-valvate prefloration.

2. The *Imbricate Prefloration.* Here the margins of adjacent parts overlap something like shingles on a roof. Of this,

also, there are several modifications. The equitant, half-equitant and triquetrous have already been described.

The *quincuncial* is that form in which there are five pieces, two entirely external, two entirely internal, and the remaining one having one edge external and one internal, as shown in the first or outer whorl of Fig. 199. The *vexillary* is the variety observed in the corollas of the Pea and many other members of the Pulse family, in which there are two lower petals overlapped by two lateral ones, which in turn are overlapped by the larger upper one.

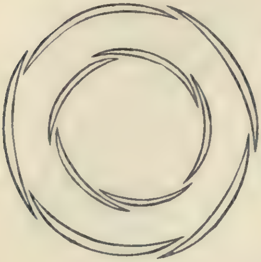


FIG. 199.

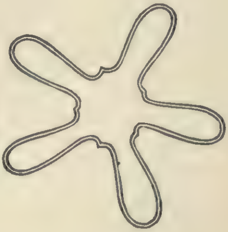


FIG. 200.

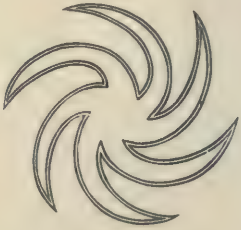


FIG. 201.

FIG. 199.—Diagram. The outer whorl represents quincuncial, the inner one, contorted prefloration.

FIG. 200.—Diagram of plicate prefloration of the Harebell.

FIG. 201.—Diagram of supervolute prefloration of Stramonium.

3. The *Contorted Prefloration* is that in which the parts are arranged with one edge invariably exterior and the other interior, giving to the bud a twisted appearance, as in the inner whorl, Fig. 199.

4. The *Plicate or Plaited Prefloration.* These terms, except when applied to the folding of a single leaf or floral organ, have reference only to those corollas or calyxes whose pieces are united. Such an organ folded lengthwise is called plicate, as the corolla of the Harebell, Fig. 200. In case the organ is both folded and twisted, as in the corolla of Stramonium, Fig. 201, it is commonly called *supervolute.*

RECAPITULATION.

- Prefoliation and Prefloration.
  - Individual Leaf.
    - 1. Inflexed or reclinate.
    - 2. Conduplicate.
    - 3. Convolute.
    - 4. Circinate.
    - 5. Plicate.
    - 6. Involute.
    - 7. Revolute.
  - Relative Arrangement.
    - Valvate Series.
      - 8. Simply Valvate.
      - 9. Induplicate-valvate.
      - 10. Reduplicate-valvate.
      - 11. Involute-valvate.
    - Imbricate Series.
      - 12. Imbricate.
      - 13. Quincuncial.
      - 14. Vexillary.
      - 15. Equitant.
      - 16. Half-equitant.
      - 17. Triquetrous.
    - 18. Contorted.
  - Calyx or Corolla when Parts are United.
    - 19. Plicate.
    - 20. Supervolute.

PRACTICAL EXERCISES.

Examine the flower-buds of the following plants with reference to the prefloration of calyx and corolla ; draw a diagram of the arrangement in each case, and apply to each the proper term descriptive of the prefloration : The Apple, the Mustard, the field Clover, the Morning-glory, the Butter-cup, the Geranium, the Buckthorn, the Grape and the Stramonium.

CHAPTER VIII.—STRUCTURE OF THE FLOWER.

When complete, the flower consists of four sets of modified leaves, constituting as many different organs, the outer set or whorl called the *calyx*, composed of individual pieces called *sepals ;* the second set called the *corolla*, made up of individual pieces called *petals ;* the third set called the *andrœcium*, made up of individual pieces called *stamens ;* and the fourth, or central set, called the *gynœcium*, made up of individual pieces called *pistils*. All of these are inserted on a shortened axis or stem called the *receptacle*. Fig. 202 is a diagram of a typical flower.

The parts are represented as separated in their order from the receptacle:

(a) Represents a whorl of three pistils, the gynæcium.

(b) A whorl of three stamens, the andrœcium.

(c) A whorl of three petals, the corolla.

(d) A whorl of three sepals, the calyx.

(e) The receptacle, the shortened axis on which all these parts are inserted; and

(f) A bract below the flower.

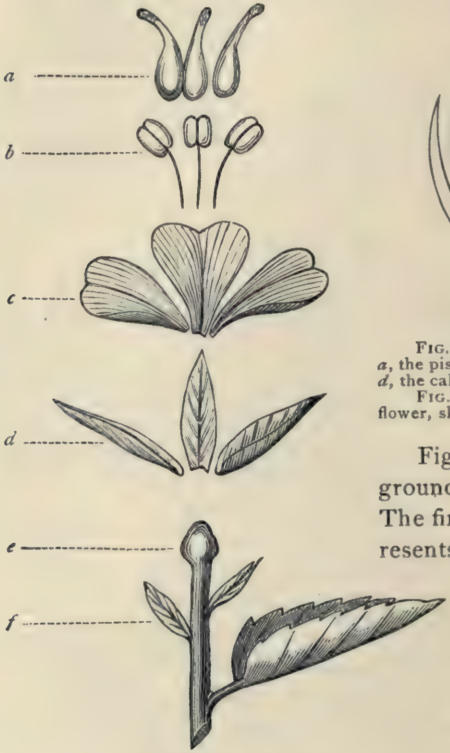


FIG. 202.

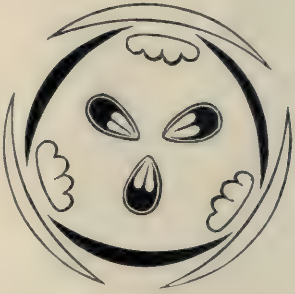


FIG. 203.

FIG. 202.—Diagram of a typical flower; *a*, the pistils; *b*, the stamens; *c*, the corolla; *d*, the calyx; *e*, the receptacle, and *f*, bract.
FIG. 203.—Ground plan of the same flower, showing relation of parts.

Fig. 203 represents the ground plan of such a flower. The first, or outside whorl, represents the calyx, the second the corolla, the third the andrœcium, and the fourth, or central whorl, the gynæcium. It will be observed that the successive whorls alternate with each other, or are arranged on the same plan as whorled leaves.

It will also be seen that in this ground plan a certain number, the number three, prevails throughout. This is called the numerical plan of the flower, a very important thing to observe in the study of flowers, since in some large groups of plants the same number prevails throughout, as, for instance, the number four in the order Cruciferæ, and the number three, or some multiple of it, in the great group of Monocotyledons. A flower constructed on the plan of one, or which possesses one sepal, one petal, etc., as is sometimes the case, is called *monomerous;* one whose parts are in twos, *dimerous;* one whose parts are in threes, *trimerous;* one whose parts are in fours, *tetramerous;* one whose parts are in fives, *pentamerous;* and one whose parts are in sixes, *hexamerous.* The commonest of these arrangements are the trimerous, the tetramerous, and the pentamerous. It must be observed that in some cases, owing either to the multiplication, suppression or coalescence of the parts of some whorls, the numerical plan is more or less obscured, but it may in most instances be discovered by careful study.

Such a flower as is represented in Figs. 202 and 203, is trimerous; since, also, it possesses all the parts which properly belong to a flower, it is *complete;* because it has the same number of parts in each whorl, and these whorls alternate with each other regularly, it is *symmetrical;* because the parts of each whorl are similar in size and shape, it is *regular;* because it possesses all the parts essential to the production of seed, namely stamens and pistils, it is *hermaphrodite,* or perfect; and because it possesses both sets of the floral envelopes, calyx and corolla, it is *dichlamydeous.* The flower of the Trillium, except that it has its stamens in two whorls of three each and its three pistils partially united, illustrates very well a typical trimerous flower, and the flowers of the Flax and Stonecrop are pentamerous flowers that closely conform to the typical flower in structure. But, while we have reason to believe that most flowers are modifications of some such form as we have described as typical, the flowers that deviate from this form are far more numerous than those which conform to it. Most of these deviations we are to regard as adaptations or modifications which the organs have undergone in relation to the surroundings of the plant, or the conditions of its existence. Even such very irregular and unsymmetrical flowers as those of the Orchids were doubtless derived from perfectly regular and symmetrical ones by slow processes of change reaching back through many thousands of generations. Evidence that this is the fact is obtained from comparing them with related plants, from a study of the development of their flowers, from the observed facts of variation in plants, and from the study of monstrous or abnormal forms of flowers that occasionally make their appearance. Monstrous flowers of the Lady's-slipper (Cypripedium spectabile) have been found that were almost perfectly regular and symmetrical. In the frontispiece is shown such a flower growing on the same stem as one which has the ordinary form of this species. The selection exercised by insects in visiting flowers for their nectar and pollen, in conjunction with the tendency which all flowers have to vary, has curiously enough been proved to be one important agency in producing irregular and unsymmetrical flowers. (See the subject of Pollination).

The more important deviations from the typical form of the flower may be classified and described as follows:

(1) *Deviations due to a Deficiency of Parts.* A flower may be defective or incomplete in almost any degree. Only a portion of a single whorl may be absent, or one or more entire whorls may be wanting. There are flowers so defective as to consist only of a single stamen, or of a single pistil, as in the little Wolffia.

A flower that lacks one of the floral envelopes is called *monochlamydeous;* one that is destitute of both calyx and corolla, *achlamydeous*, or naked; if it has pistils, but is destitute of the staminal whorl or andrœcium, it is called *pistillate*, or female; if it possesses stamens, but not pistils, it is described as *staminate*, or male; and if it be destitute of both, it is called *neuter*. Such showy neutral flowers are seen in the border of the cymes of the wild Hydrangea and Cranberry-tree.

Some plants, as the Begonias, Castor-oil Plant and Maize, bear two kinds of flowers, staminate and pistillate, on the same plant. Such a plant is described as *monœcius*. In the case of some others the staminate and pistillate flowers are borne by different plants of the same species; this is true of Sassafras, many Willows, the Tree of Heaven, etc. Such plants are *diœcious*. The Maple is an example of a tree which produces staminate, pistillate and hermaphrodite flowers all on the same tree. Such a plant is termed *polygamous*.

(2) *Deviations due to a Rodundancy of Parts.* This is scarcely less common, and may apply to any of the floral organs. So-called

"double" flowers are flowers in which the petals or sepals are multiplied beyond the normal number, as in the cultivated Rose, the Camellia, and the garden Ranunculus. In the Cactuses, the stamens, and in the wild Buttercups, the pistils, are very numerous. Sometimes the multiplication of parts takes place by the formation of new whorls, and sometimes by an increase in the number of parts of the same whorl.

Both incompleteness and redundancy tend more or less to obscure the numerical plan, but usually it may still be discerned in one or more of the whorls.

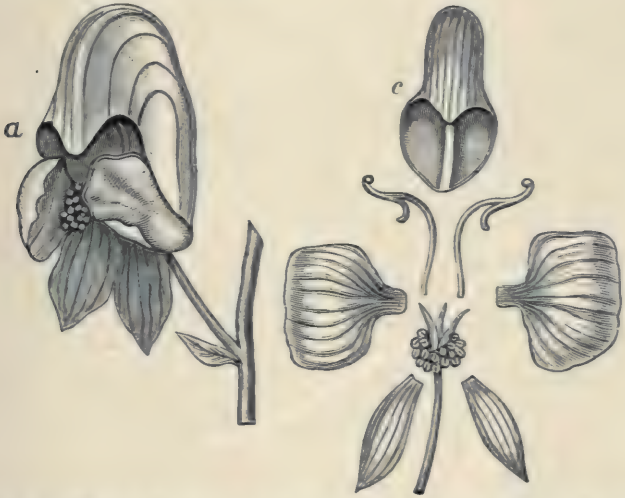


FIG. 204.—Flower of Aconite : *a*, as it appears when fully expanded ; *c*, with the parts separated, showing the hooded upper sepal, the two large lateral sepals and the two smaller ones ; underneath the hood are the two petals.

(3) *Deviations due to the Anteposition of parts.* Normally, as has been stated, the whorls alternate, but occasionally they are anteposed, or have the pieces of successive whorls placed one in front of the other. In the Barberry and the Blue Cohosh, for example, the stamens come opposite to the petals, and in the Iris the stigmas (which are the upper part of the pistil) come opposite the stamens.

(4) *Deviations due to the Irregularity of Parts.* Irregularity in the size, shape or coloring of parts, particularly of the calyx and corolla, are very common. In the Figwort and Mint families

regularity is the exception and not the rule, and there is no known member of the family of Orchids that is not very irregular. Fig. 204 represents the irregular flower of Monk's-hood or Aconite. In the outer whorl there are five sepals, the upper of which is hooded, and the two lateral ones differ from the two lower in size and shape. From the second whorl, or corolla, all but two pieces are wanting, and these, though really petals, bear little resemblance to ordinary ones in shape. *a* shows the flower as it appears naturally, and *c* represents the same with the parts of the calyx and corolla separated, showing their shape and relations.

(5) *Deviations due to the Union of Parts.* There is perhaps nothing which contributes so much to obscure the plan of the flower and cause deviations from the typical form as this.

The growing together may take place in two ways. Either the parts of the same whorl may coalesce partly or wholly, or parts of different whorls may become more or less united. The former is termed *cohesion*, the latter *adhesion* or *adnation*. Cohesion, either complete or partial, may take place between the members of any set of floral organs, and any two sets may adhere partly or wholly. Even organs so different in their functions as stamens and pistils not infrequently become united, as in the Orchis family.

Practical Exercises.

Examine flowers of the following plants: The Tiger Lily, the house Geranium, the Morning-glory, the Butter-cup, and the Rose, and determine, (1) the numerical plan of each flower, (2) draw a ground plan of each, representing, as in Figs. 195 and 203, the number and relation of parts, and note in each what deviations from the typical flower occur.

CHAPTER IX.—THE TORUS, CALYX AND COROLLA.

The Torus. This is *the shortened axis on which the other floral organs are inserted.* In form it is commonly *convex* or *flat*, but sometimes it is conical, as in the Strawberry, sometimes long and beaked, as in the Geranium, sometimes *concave* or hollow, as in the Rose and Fig, sometimes *top-shaped*, as in Nelumbium, and sometimes *stipitate*, as in Silene and Gynandropsis, where the middle portion is elongated into a stalk, separating some of the floral whorls from each other.

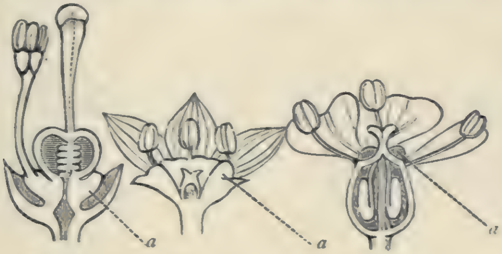


FIG. 205. FIG. 206. FIG. 207.

FIG. 205.—Orange flower, cut lengthwise and deprived of its petals and all but one cluster of its stamens, to show the hypogynous disc, *a*.
FIG. 206.—Flower of Sumach, cut lengthwise, showing perigynous disc, *a*.
FIG. 207.—Flower of Æthusa, cut lengthwise to show the epigynous disc, *a*.

Not infrequently the receptacle produces a fleshy outgrowth from its margin, called a *disc.* If this remains wholly underneath the pistils, as in Fig. 205, it is said to be *hypogynous;* if it grows up around and partially but not wholly envelops them, as in Fig. 206, it is called *perigynous;* and if it completely envelops them and becomes adnate to them, so as to appear to spring from the top of the ovary, as in Fig. 207, it is said to be *epigynous.*

The axis of a flower cluster, if very short and resembling in shape the receptacle of a single flower, is also called a receptacle, or a *common receptacle.* The floral axes of the Dandelion, Lettuce and Clover are examples.

The Calyx. This is the outer of the four series of floral leaves, and its parts ordinarily bear a closer resemblance to true leaves than do the other organs of the flower. They are more commonly green in color, and are then described as *foliaceous*, but in some flowers they have the color of petals or some lively hue other than green, in which case they are described as *petaloid.* The latter are illustrated in the sepals of the Larkspur, Columbine and showy Lady's-slipper. When the petals are distinct from each other or ununited, the calyx is described as *chorisepalous,* or, less correctly, as polysepalous, and when they are united either partially or wholly, it is called *gamosepalous.* In a gamosepalous calyx where the union of sepals is incomplete, the united portion is called the *tube,* while the free or ununited portion is termed the *limb,* and the orifice of the tube is called the *throat.*

In flowers belonging to the natural order Compositæ, the calyx has its tube united to the ovary, while its limb is produced into a hairy, scaly or spiny crown called a *pappus.* The down, by means of which the ripe fruits of the Dandelion, Thistle and Lettuce are wafted on the wind, is an illustration. In the Valerian and Teasel families, the calyx-limb forms a pappus in a similar manner.

In form, the calyx may be *regular* or *irregular:* regular, if its parts are evenly developed ; irregular, if some of the sepals are larger or different in shape from others ; or in the case of a gamosepalous calyx, if either the tube is unequal-sided or the divisions of the limb are of unequal size or shape. Among the more commonly occurring forms of the gamosepalous calyx are the *tubular* or tube-shaped, the *rotate* or wheel-shaped, the *campanulate* or bell-shaped, the *hypocrateriform* or salver-shaped, the *urceolate* or urn-shaped, and the *bi-labiate,* forms which correspond to those of the corolla, presently to be described.

The calyx very commonly remains after the corolla and stamens have withered, and sometimes endures even until the ripening of the fruit; in either case it is said to be *persistent.* Not infrequently, however, it falls away at the same time with the corolla and stamens, when it is described as *deciduous.* More rarely it falls off when the flower begins to open ; in this case it is described as *caducous;* the Poppy and May-apple afford examples.

The calyx often becomes more or less adherent to the ovary or base of the pistil, and it is a matter of much importance in the study of flowers to observe whether such adhesion has taken place or not, and if so, to what extent. When free from the ovary or situated wholly beneath it, it is said to be *non-adherent*, *inferior* or *hypogynous;* when its tube becomes adnate to and partially but not wholly envelops it, it is said to be *half-adherent*, *half-superior* or *perigynous;* and when it completely envelops it, so that the limb appears to arise, distinct from other organs, from its very top, it is said to be *adherent*, *superior* or *epigynous*. When corolla and stamens spring from the throat of the calyx-tube, and the latter more or less completely envelops the ovary, but is not adnate to it, the calyx is still, of course, hypogynous, but the petals and stamens, being borne around the pistil, are described as perigynous. If the calyx grows fast to the ovary below but has its tube prolonged above it, bearing upon it the adherent petals and stamens, as in the Fuchsia and Evening Primrose, calyx, corolla and stamens are described as perigynous, and not as epigynous.

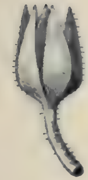


FIG. 208.

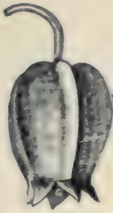


FIG. 209.

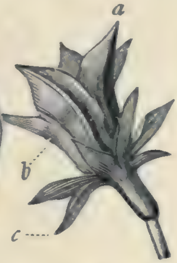


FIG. 210.

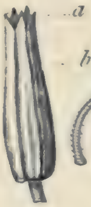


FIG 211.

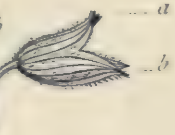


FIG. 212.

FIG. 208.—Chorisepalous calyx of a species of Oxalis, somewhat enlarged.

FIG. 209.—Gamosepalous calyx of a species of Abutilon. The inflated tube is five-winged.

FIG. 210.—Campanulate calyx of a species of Hibiscus. *a*, one of the divisions of the limb; *b*, the tube; and *c*, one of the leaves of the epicalyx.

FIG. 211.—Tubular calyx of Saponaria officinalis; *a*, the five-toothed limb; and *b*, the tube.

FIG. 212.—Bi-labiate calyx of Salvia urticifolia, somewhat enlarged; *a*, three-toothed upper lip; and *b*, two-toothed lower lip.

Sometimes we find exterior to the calyx or even adherent to it a whorl of bracts more or less resembling a calyx in appearance and structure. This is the case with the Hibiscus, the Strawberry and the Cinquefoil. Such an organ is called an *epicalyx*. See Fig. 210.

In some cases bracts situated below the flower become more highly colored than the floral organs themselves, as in the

Painted-cup and in some Euphorbias. These should not be confounded with the floral organs proper.

The Corolla. This is usually the most showy portion of the flower. It is seldom green in color, but, like the sepals of the calyx, its parts often bear more or less resemblance in shape to leaves. In some instances all the parts of a complete leaf may still be recognized in them, as, for example, in the petals of the Saponaria, Fig. 213. The upper or expanded portion evidently corresponds to the blade of a leaf and, like it, is termed the *lamina*. At the junction of the latter with the lower or stalk-like portion are observed two little projections, *b*, which, in the form of wing-like appendages, may be traced downward nearly to the base of the stalk. These undoubtedly represent stipules, and their free portion is technically called the *corona*. The stalk, *c*, in this case made up of petiole and the adherent portion of the stipules, is called the *claw* or *unguis*. In the great majority of petals, however, the corona is wanting, and in many cases also the claw. There is reason to believe, moreover, that the lamina is not in all cases a modified leaf-blade. In some instances it is rather to be regarded as a modified stipule, the petiole and blade having become aborted. In some species of Rose, for example, we may trace in the leaves beneath the flower a gradual transition, as the inflorescence is approached, between leaves that are complete and those which have entirely lost their blades and petioles, and have come to consist wholly of well-developed stipules. In case such petals are clawed, the claw, of course, is not to be regarded as a petiole, but as a stalk-like contraction of the base of the stipule.

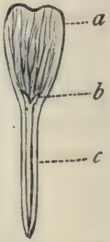


FIG. 213.—Petal of Saponaria, one of the Pink family. *a*, blade; *b*, corona; *c*, claw.

The lamina is most commonly a flat expansion, resembling in this respect the majority of leaf-blades, but this is not always the case; it may be thread-like or *filiform*, club-shaped or *clavate*, spurred or *calcarate*, sac-shaped or *saccate*, etc. The flattened kinds present almost as great a variety of shapes as those of leaf-blades, and, like them, may have their margins entire or variously indented, incised, lobed, parted or fringed. The terms already learned in leaf-description are therefore also applicable, for the most part, in the description of petals.

Where the petals are not at all united with each other, the corolla is described as *choripetalous*, or, less correctly, as *polypetalous*. If the distinct petals are four in number and arranged in the form of a cross, as they are in the Cress family, it is called *cruciform;* if the petals are five and short-clawed or clawless and spreading, like those of the wild Rose, it is called *rosaceous;* if there are five long-clawed petals, having the claws concealed in the tube of a gamosepalous calyx, as in the Pink, it is called *caryophyllaceous*, Fig. 280; when it is shaped like the irregular flower of the Pea or Genista, it is called *papilionaceous*, Figs. 214. 215 and 216; when calyx and corolla each consist of three pieces closely resembling each other in form and color, as in the Lily and Tulip, the flower is called *liliaceous;* and when, as in the Orchidaceæ, the floral leaves are epigynous, and calyx and corolla are in whorls of three pieces each, and one of the petals, called the *lip*, has a shape markedly different from the rest, it is called *orchidaceous*. In flowers like the latter two, where calyx and corolla closely resemble each other, they are commonly not distinguished by separate names, but the two together are called the *perianth*.

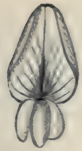


Fig. 214.

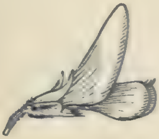


Fig. 215.

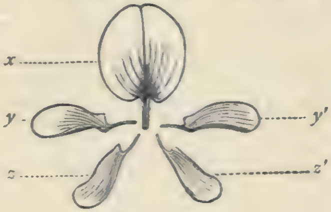
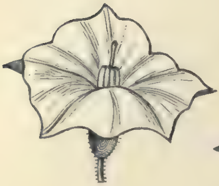


Fig. 216.

Fig. 214.—Flower of Genista, slightly enlarged, in front view.
Fig. 215.—The same in lateral view.
Fig. 216.—The petals of the same separated. *x* is the *vexillum* or standard; *y*, *y'*, the *alæ* or wings, and *z*, *z'*, the two petals which compose the *carina* or keel.

But the petals very often become more or less united. In this case the corolla is described as *gamopetalous*. The united portion is called the *tube*, and the free portion, the *limb*, as in the calyx.

A gamopetalous corolla is caled *rotate*, or wheel-shaped, when the tubular portion is short, and the divisions of the limb radiate from it like the spokes of a wheel, as in the corolla of the Potato, Fig. 217 ; *campanulate*, or bell-shaped, when shaped like the Harebell, Fig. 218 ; *urceolate*, when oblong or globular, with the mouth somewhat contracted, as in the flower of the Wintergreen, Fig. 219 ; *infundibuliform*, or funnel-shaped, when it flares like a funnel, as in the Morning-glory, Fig. 220 ; *hypocrateriform*, or salver-shaped, when the slender, tubular portion is crowned by a limb expanded at right angles to it, as in Phlox, Fig. 221 ; *tubular*, when the limb is small or scarcely spreading, and the tube is elongated, as in the flower of Spigelia, Fig. 222 ; *ligulate*, when, as in Fig. 223, the lower portion is tubular, but the upper flattened and strap-shaped ; *bilabiate*, when, as in the flower of the Deadnettle and Sage, Fig. 224, there are two lips ; it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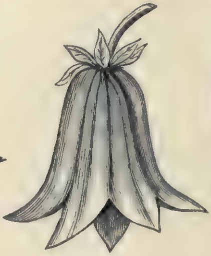
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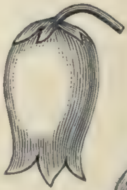
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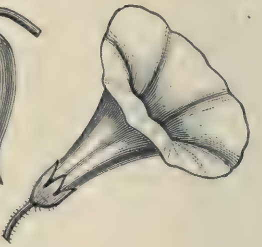
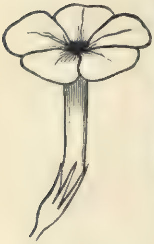


FIG. 220.

FIG. 217.—Flower of Potato, illustrating rotate corolla.
FIG. 218.—Flower of Harebell, illustrating campanulate corolla.
FIG. 219.—Flower of Wintergreen, illustrating urceolate corolla.
FIG. 220.—Flower of Morning-glory, illustrating infundibuliform corolla.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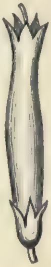
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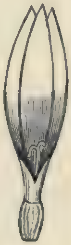
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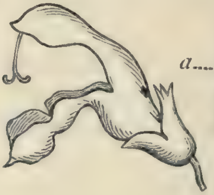
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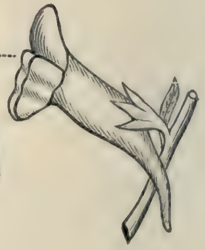


FIG. 225.

FIG. 221.—Flower of Phlox, illustrating hypocrateriform corolla.
FIG. 222.—Flower of Spigelia, illustrating tubular corolla.
FIG. 223.—Flower of Crysanthemum, one of the Compositæ, illustrating a ligulate corolla.
FIG. 224.—Bi-labiate flower of Sage. The corolla is also ringent.
FIG. 225.—Personate corolla of Linaria vulgaris. The corolla is also calcarate at the base. The thickening, *a*, is called the palate.

is also *ringent*, if the lips spread wide apart, as in the last figure; and if they are closed, and have thickened lips, as in Snap-dragon and Linaria, it is *personate*. A gamopetalous corolla may also be *saccate* or *calcarate*, the same as one whose petals are distinct. The corolla of Linaria, Fig. 225, is both personate and calcarate.

The margins of gamophyllous calyxes and corollas may be variously indented or lobed, the same as those of leaves, and the same terms are used in describing them.

PRACTICAL EXERCISES.

Study the torus, calyx and corolla of the following flowers, observing carefully their structure and describing them fully, using the proper descriptive language of botany: Those of the Petunia, Strawberry, Wild Lupine, Water-lily, Dandelion, Lady's slipper, Lobelia, Rose, Pæony, and Wallflower. State also, from your examination of them, which of these flowers have a disc, what its shape is in each case, and whether it is hypogynous, perigynous or epigynous.

CHAPTER X.—THE STAMENS, OR ANDRŒCIUM.

The stamens are the male organs of reproduction, and each stamen, when complete, consists of a *filament*, or stalk, which is not essential, and an *anther*, the essential portion, which contains in its interior a fine powdery dust, called *pollen*. See Fig. 226.

Stamens are said to be *definite* in number when so few as to be readily counted, as in the flowers of the Barberry, Mustard and Geranium, and *indefinite* when very numerous, making it difficult to count them, as in the Buttercup, the Rose, and the Water-lily.

As to their insertion, they may be situated on the receptacle, as in the Poppy, when they are said to be *hypogynous;* or they may be borne on the margin of the calyx-tube or of the disc, as in the Apple and Cherry, when they are said to be *perigynous;* or they may be borne on the top of the ovary, as in the Fennel and Madder, when they

FIG. 226.—A stamen, consisting of a pollen-bearing part, the anther, *a*, and a stalk or filament, *b*.

are called *epigynous*. See Figs. 227, 228 and 229. In the majority of cases where the corolla is gamopetalous, the stamens are inserted on its tube, as in the Phlox; they are then described as *epipetalous*. Sometimes they are inserted on or grow fast to the pistils, as in the Orchidaceæ, Fig. 230, when they are called *gynandrous*.

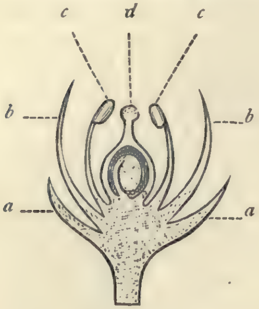


FIG. 227.

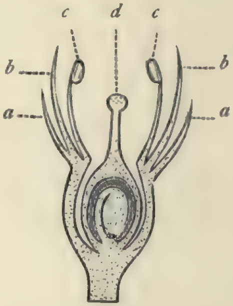


FIG. 228.

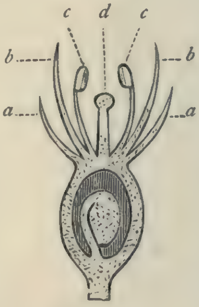


FIG. 229.

FIG. 227.—Diagram of flower showing hypogynous calyx, corolla and stamens.
FIG. 228.—Diagram of flower showing perigynous corolla and stamens.
FIG. 229.—Diagram of flower showing epigynous calyx, corolla and stamens. In each of these three figures, *a* represents the calyx; *b*, the corolla; *c*, a stamen; and *d*, the pistil.

Very commonly, stamens may become more or less united with each other. This union may take place by the filaments, or by the anthers, or by both. By their filaments they may be united into one or into more than one set. When in one set, as in the Mallow, Fig. 231, they are called *monadelphous;* when in two sets, as in the Pea, Fig. 232, they are termed *diadelphous;*

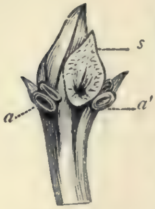
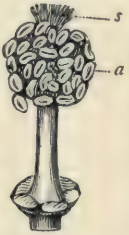


FIG. 230.



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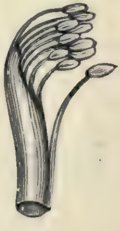


FIG. 232.

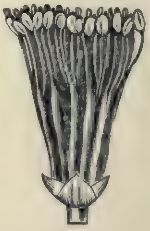


FIG. 233.

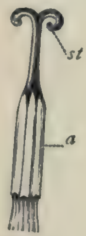


FIG. 234.

FIG. 230.—Gynandrous stamens of the Lady's-slipper, one of the Orchidaceæ; *s*, represents the stigma, and *a a'*, the anthers; they are grown together.
FIG. 231.—Monadelphous stamens of the Mallow; *s*, the stigmas, and *a*, the anthers.
FIG. 232.—Diadelphous stamens of the Pea. In this flower, one stamen stands by itself, while the other nine are united by their filaments.
FIG 233.—Polyadelphous stamens of the Orange.
FIG. 234.—Syngenesious stamens of the Dandelion; *a*, the anthers, and *st*, the stigma.

when in three sets, as in some Hypericums, *triadelphous*, etc.; and when in a considerable number of sets, as in the Orange, Fig. 233, they are called *polyadelphous*. When stamens are united by their *anthers*, as they are in the Sunflower, Dandelion (Fig. 234), and other Compositæ, they are called *syngenesious*.

In some flowers, as in many Mints and Figworts, there are four stamens, two of them longer than the other two; such stamens are said to be *didynamous*. In the Mustard and other members of the Cress family, there are four long and two short ones; the stamens of such flowers are said to be *tetradynamous*.

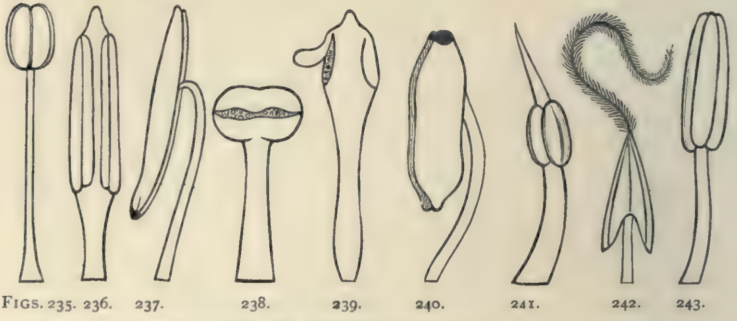
Occasionally the filament is wanting, and the anther is then described as *sessile*. Sometimes, however, the anther is wanting, or no longer functional; such a stamen is described as *sterile* or abortive.

The Filament. This probably corresponds, in most cases at least, to the petiole of the leaf, while the anther is regarded as homologous with the blade. It assumes a great variety of forms in different flowers. Sometimes it is *capillary*, or very slender and hair-like, as in some grasses; sometimes it is *filiform*, or thread-like, as in many of the Rosaceæ; sometimes it is *petaloideous*, or petal-like, as in some of the stamens of the White Water-lily; sometimes it is toothed, as in some species of Onion; sometimes it is appendaged, as in the Milk-weed; most commonly it is simple, as in the Geranium, but sometimes it is branched, as in the Castor-oil Plant. Its different forms commonly bear some relation, more or less evident, to the mode of pollination.

The Anther. The anther is usually two-lobed and two-celled, that is, contains two pollen-sacs, but occasionally we find it twice as many lobed and celled, and, on the other hand, we sometimes find stamens where, as in those of the Hollyhock, the two normal pollen-sacs have become confluent into one.

There are different ways in which the anther may be inserted on its filament. When it stands erect on the end of the filament, as in Fig. 235, it is described as *innate*; when the two lobes of the anther appear to grow fast to the side of the filament, or the latter appears to be produced through the middle of the anther, as in Fig. 236, it is called *adnate*; and when the anther swings freely on the slender apex of the filament, as in Fig. 237, it is called *versatile.*

It is of importance, also, to observe which way the anther faces in the flower, whether inward toward the pistil, or outward from it, or whether its position is indifferent. Most versatile anthers are indifferent, and other kinds also are frequently so, especially when the filaments are long and slender. Anthers which face outward are described as *extrorse*, while those which face inward are *introrse.*



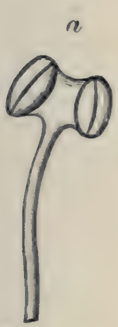
FIGS. 235. 236. 237. 238. 239. 240. 241. 242. 243.

FIG. 235.—Stamen of Saxifrage, showing innate anther.
FIG. 236.—Stamen of Magnolia, showing adnate anther.
FIG. 237.—Stamen of Agave, showing versatile anther.
FIG. 238.—Stamen of Alchemilla, showing anther dehiscing transversely.
FIG. 239.—Stamen of Barberry, showing anther dehiscing by valves.
FIG. 240.—Stamen of Rhododendron, with anther dehiscing by pores or openings at the apex.
FIG. 241.—Stamen of Asarum, with connective prolonged beyond the top of the anther.
FIG. 242.—Upper portion of stamen of Oleander, with connective prolonged and forming a plumose appendage at the top of the anther.
FIG. 243.—Stamen of Butomus, showing four-celled anther.

Anthers split open, or *dehisce*, in a variety of ways, to shed their pollen. When the dehiscence is lengthwise of the anther, as in Figs. 235 to 237, inclusive, it is said to be *longitudinal;* when crosswise, as is shown in Fig. 238, it is described as *transverse;* when it opens laterally by lids, as in the Barberry, Fig. 239, it is called *valvular;* and when the discharge of the pollen is by pores at the apex, as in most members of the Heath family, Fig. 240, the dehiscence is called *porous.*

The Connective. The connective is that part of the anther which unites the two lobes, or what appears to be the continuation of the filament through the anther. In some anthers, as for example those of Wild Ginger (Asarum), Fig. 241, and the Oleander, Fig. 242, it is prolonged beyond the top of the anther;

in others, as in Calaminth and Sage, Figs. 244 and 245, it is broad, or strongly developed transversely, and separates rather widely the two lobes ; in the latter the lobes are very wide apart, and one of them becomes abortive, while the other remains fertile ; in others still, as the Hollyhock, the connective disappears and the two equal lobes become confluent into one, Fig. 246, and in the Globe Amaranth of the gardens one of the cells entirely disappears, as well as the connective, while the other is attached by its middle to the end of the filament, as in Fig. 247. Such an anther, as the last, has been termed *dimidiate*.



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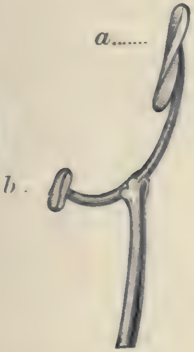

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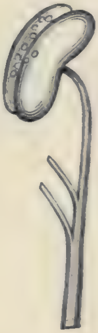


FIG. 246.

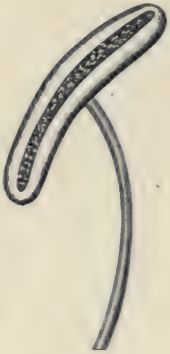


FIG. 247.

FIG. 244.—Stamen of Calaminth, showing anther with broad connective, *a*.

FIG. 245.—Stamen of Sage, with elongated connective hinged to the top of the filament. One lobe of the anther, *a*, contains pollen, the other, *b*, is sterile.

FIG. 246.—Stamen of Hollyhock, with anther lobes confluent.

FIG. 247.—Stamen of Globe Amaranth, with anther consisting of but one lobe, and that attached by its middle to the end of the filament.

The Pollen. This commonly consists of fine, dust-like particles, produced within the cells or loculi of the anthers. It is for the production of this flower-dust that the stamens exist, and when it is shed their work is done, and they usually wither away. It is by the agency of these powdery particles that the pistil is made to produce seed. Each pollen grain is commonly a single cell with two walls, the outer, called the extine, thickened and often peculiarly marked, the inner, called the intine, thin, highly extensible, and inclosing a semi-fluid substance called the *fovilla*.

Some idea of the variety of forms of these grains may be gained from an inspection of Figures 248 to 253 inclusive. Fig.

248 represents a pollen grain of the Mallow; Fig. 249, that of a Lily; Fig. 250, that of Chicory; Fig. 251, that of Evening Primrose, and Fig. 252, that of the Pine. They are all considerably magnified.

When a pollen grain is placed upon the stigma of a flower of the same species, the outer coat of the grain bursts, and by the extension of the inner one, a tube is formed which penetrates the tissues of the style. Fig. 253 represents a germinating pollen grain.

Pollen grains are produced in enormous numbers, particularly in plants that are dependent on the wind for the transfer of the pollen from the stamens to the pistils, as in the Pines. Some one has estimated that a single plant of the Chinese Wisteria, when well developed, may produce during one flowering season as many as 27,000,000 pollen grains. A common Pine tree, in all probability, produces a vastly greater number than this.

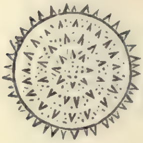


Fig. 248.

Fig. 249.

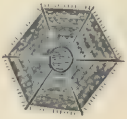


Fig. 250.

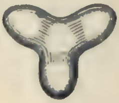


Fig. 251.

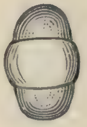


Fig. 252.

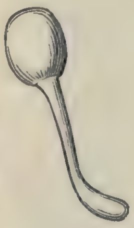


Fig. 253.

Fig. 248.—Spinose pollen grain of the Mallow.
Fig 249.—Pollen grain of Lily.
Fig. 250.—Pollen grain of Chicory.
Fig. 251.—Pollen grain of Evening Primrose.
Fig. 252.—Pollen grain of Pine.
Fig. 253.—Pollen grain in process of germination.

All highly magnified.

It is to be observed that in plants that are dependent on the wind for the transfer of their pollen, the grains are usually dry and powdery; while those that depend on insects for this work, usually produce sticky pollen. In some instances, however, the pollen does not separate into grains, but remains in masses, as in the flowers of the common Milk-weed and those of most Orchidaceæ. These pollen masses are termed *pollinia*. The pollinia of the Milk-weed are illustrated in Fig. 254.

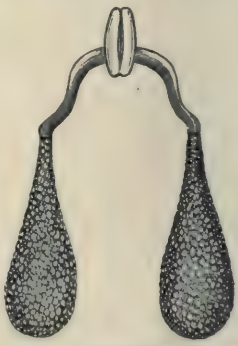


Fig. 254.—Pollinia of the Milk-weed.

PRACTICAL EXERCISES.

Examine the stamens of the freshly opened flowers of the following plants: The Pumpkin, the common Mallow, the Tiger Lily, the Cherry, the Musk Plant, and the wild Cucumber, and ascertain in each case (1) what parts are present; (2) whether the stamens are distinct or whether they are united to each other or to other organs; (3) whether they are hypogynous, perigynous, or epigynous; (4) whether the position of the anthers is extrose, introse or indifferent; (5) whether the anthers are one-celled, two-celled or four-celled; (6) the character of the connective; (7) whether the anthers are innate, adnate or versatile; (8) whether their dehiscence is longitudinal, transverse, valvular or porous; (9) the shape and character of the filaments; (10) the shape and markings of the pollen grains. In order to study the pollen grains, seize by means of a delicate pair of forceps, a stamen whose anther is just dehiscing, tap the latter gently on the surface of a clean sheet of white paper, and then examine carefully the adhering grains by means of a good lens. The pollen grains of many plants are so minute that they cannot be satisfactorily studied in this way; the student had better, therefore, if possible, use for the purpose a compound microscope.

CHAPTER XI.—THE PISTILS, OR GYNÆCIUM.

The pistil is the female organ of reproduction of the flowering plant. In the Pine and related plants, it consists of an open leaf or scale, which bears but does not inclose the

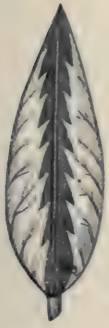


FIG. 255.

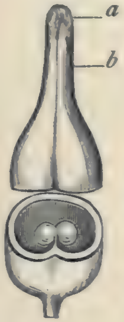


FIG. 256.

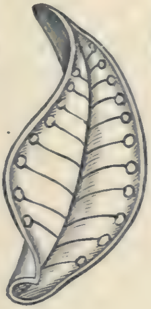


FIG. 257.

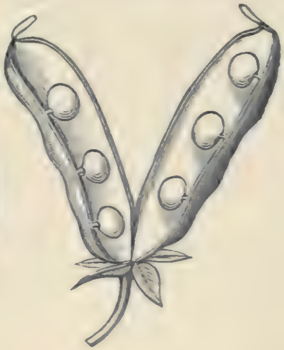


FIG. 258.

FIG. 255.—A leaf folded so as to illustrate the structure of a simple pistil or carpellary leaf.

FIG. 256.—A simple pistil cut transversely to show the cavity of the ovary and the ovules. *a* is the stigma and *b* the style.

FIG. 257.—Follicle of Caltha, opened out to show its resemblance to a leaf.

FIG. 258.—Pea-pod, laid open to show the placenta, corresponding to the infolded leaf-margins, and bearing a double row of ovules.

ovules; but in most flowering plants it forms a closed sac which envelops and protects them. Pistils of the former kind are called *gymnospermous;* they are usually quite simple in their structure; those of the latter kind are termed *angiospermous*, and they exist in a great variety of forms. When complete, an angiospermous pistil consists of *ovary*, *style* and *stigma.*

The ovary, usually the basal portion, is the part which contains the ovule or ovules; the stigma, commonly the apical portion, is the part which receives the pollen, and the style the part which connects the ovary and stigma, Fig. 256. The former two are essential, while the latter is not. When the style is wanting, as is frequently the case, the stigma is said to be sessile.

The pistil, though greatly changed from the ordinary form of the leaf, still in many cases clearly shows its relationship to one, and it is possible for us to trace the correspondence of parts. If we imagine an ordinary leaf, like that of the Cherry, to be folded in such a manner as to bring the upper surface and margins interior, as in Fig. 255, the lower portion would correspond to the ovary, the infolded margins projecting into its cavity to the ovule-bearing portion, or *placenta*, the apical portion to the stigma, and the narrow upper portion of the leaf adjacent to it, to the style. If the ripe follicle of the Columbine or of the Caltha be opened out, as in Fig. 257, the correspondence in structure to the infolded leaf above described, will be at once evident. That this is the real nature of the pistil is further shown by the study of its development, and by the study of monstrous forms of it, in which we often find more or less complete reversion, or return to the ordinary condition of a leaf.

If a Pea-pod be carefully laid open and examined, the young peas will be found to occupy a double row along one of the sutures of the pod, as illustrated in Fig. 258. This portion corresponds to the infolded edges of the leaf, and when the pod splits open it does so along the line separating these edges. This line is called the *ventral suture.* But it also dehisces along the opposite side, called the *dorsal suture*, and this corresponds to the mid-rib of the leaf. A leaf thus transformed into an ovule-bearing organ is commonly called a *carpel* or *carpophyll*, and the pistils of the Caltha, the Columbine and the Pea are each made up of single carpels. Such pistils are described as *apocarpous.*

Other examples of apocarpous pistils are those of the Buttercup, Blackberry, Golden-seal and Aconite. But pistils, more than any other floral organs, are liable to cohere more or less completely into compound forms. Such pistils are described as *syncarpous*, Figs. 259 and 260.

The union may have all degrees of completeness. Sometimes, as in Saxifrage, Fig. 261, the ovaries are united below, but distinct above; often they are completely united, while the styles and stigmas are distinct, as in the Flax and Hypericum, Figs. 260 and 262; sometimes the union is complete, even to stigmas. Even in these cases, however, traces of the composite character of the structure usually still remain, either in the lobing of the stigma or ovary, or in the internal structure of the latter organ. If, for instance, the pistil is three-carpelled, the fact may be indicated by the division of the ovary into three cells, or by the fact of its possessing three double rows of ovules on its walls. While, however, the number of cells in the ovary is usually indicative of the number of carpels of which the pistil is composed, it must not be taken as an infallible guide, but other structural points must be taken into consideration, for instances are known where, by the growth of false partitions from the dorsal sutures of the carpels, the number of cells in the ovary

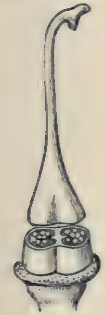


FIG. 259.

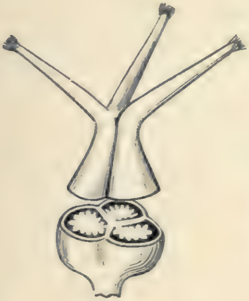


FIG. 260.

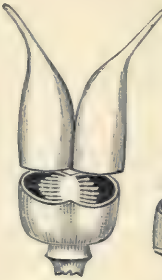


FIG. 261.

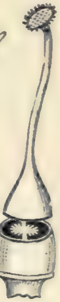


FIG. 262.

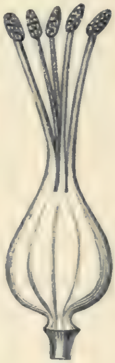


FIG. 263.

FIG. 259.—Syncarpous pistil of Scrophularia, made up of two carpels. The ovary is cut transversely, to show the two-celled ovary.

FIG. 260.—Syncarpous pistil of a species of Hypericum, composed of three carpels.

FIG. 261.—Pistil of Saxifrage, having the two carpels only partially united.

FIG. 262.—Two-carpelled pistil of Henbane, with the ovary cut transversely to show the placentæ.

FIG. 263.—Pistil of Flax, consisting of five carpels, the ovaries united, but the styles and stigmas distinct.

has become double the number of carpels. Similarly, though the number of lobes of the stigma usually indicate the number of carpels, this is not always the case.

Placentation. According to the character of the placentation, syncarpous pistils may be divided into four kinds:

1. Those with *marginal placentæ.* In this case the ovary has but one cell or loculus, and the ovules are borne on the infolded edges of the component carpels, as shown in Fig. 264. Here, the number of double rows of ovules corresponds with the number of carpels which compose the pistil. Many simple pistils, as those of the Pea and Caltha, also have this kind of placentation.

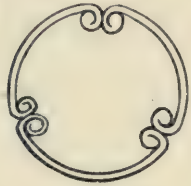


FIG. 264.

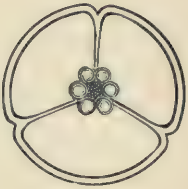


FIG. 265.

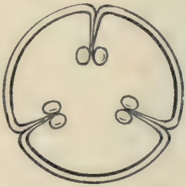


FIG. 266.

FIG. 264.—Diagram of ovary, with marginal placentæ.
FIG. 265.—Diagram of ovary, with axile placentæ.
FIG. 266.—Diagram of ovary, with marginal placentæ, but with the latter extended toward the centre of the ovary, constituting a form intermediate between those represented in Figs. 264 and 265.

2. Those with *axile placentæ.* In this case, the ovule bearing margins of the carpel grow inward until they meet in the centre, forming an ovary which usually has as many loculi as there are carpels composing it, as in Fig. 265. Thus the ovary with axile placentæ is a modification of one with marginal placentæ, and, as might be expected, we find every gradation between the two. Fig. 266 represents an intermediate form, in which the marginal placentæ are prolonged inward, but do not meet.

3. Those with *superficial placentæ.* In this case, the ovules are not borne on the edges or infolded margins of the carpels, or at any rate, not upon these alone, but are distributed over their inner surface. This form of placentation is comparatively rare. It is illustrated in the compound multi-locular pistil of the Water-lily, and in the simple, or slightly united, pistils of the Flowering-rush (Butomus).

4. Those with *basilar* or *free-central placentæ.* Here, the ovules are borne on a column which rises free from the bottom of the ovary, as in the Primrose and the Soapwort. This form of placentation is illustrated in Figs. 267 and 268.

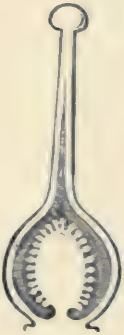


FIG. 267.

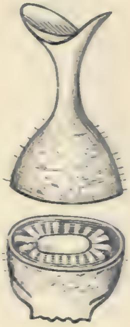


FIG. 268.

FIG. 267.—Pistil of Primrose, with ovary cut vertically to show free-central placentation. Enlarged.

FIG. 268.—Pistil of Pinguicula, enlarged and cut transversely to show free-central placentation.

An ovary that has but one cavity, as the Pea-pod, and as shown in Figs. 256 and 264, is termed *unilocular;* one that, as in Figs. 259 and 261, has two cavities, is called *bilocular;* one that, as in Figs. 260 and 265, has three cavities, is *trilocular;* and one that has many cavities is called *multilocular*, or *plurilocular*.

As has already been stated, the ovary is often more or less adherent to the calyx. When it is entirely free from the latter, it is said to be *superior;* when partially adhering, it is *half-superior*, or *half-inferior;* and when completely enveloped in the adnate calyx-tube, it is *inferior*.

The Style. *This is the stalk of the stigma*, or the part of the pistil which connects the stigma with the ovary. It sometimes contains a narrow canal or passage-way leading from the one to the other, but more commonly this is wanting, and the interior is composed of thin-walled cellular tissues. It most commonly arises from the summit of the ovary, in which case it is described as *terminal* or *apical;* in some cases, however, it is inserted on one side, as in the Strawberry, when it is called *lateral*, or it may even be attached to the base of the ovary, as in *Alchemilla*, when it is described as *basilar*. Very commonly the style falls away after the process of fertilization is completed, in which case it is termed *deciduous*, but sometimes it remains and forms a part of the fruit; it is then called *persistent*. This is the case in Snapdragon and Scrophularia. As regards its form, it may be *filiform* or thread-like, as in the Fuchsia; *clavate* or club-shaped, as in the Orange; *subulate* or awl-shaped, as in Cyclamen; *petaloideous* or petal-like, as in Iris. It may also be either simple or branching. In the case of syncarpous pistils, the styles may be united to any degree, from a slight union at the base to one which is complete to the apex. In these cases the terms used in the description of leaf-margins may be applied to them to indicate the degree of separation, as trifid, quadrifid, tripartrite, quadripartrite, trilobate, quadrilobate, etc. So far as the surface is concerned, it may be smooth or it may be hairy, and the hairs may be of various kinds. In the Compositæ the upper part is covered with rigid, collecting hairs, serviceable in brushing out the pollen from the anthers, and in some members of the Leguminosæ a ring or fringe of stiff hairs, just beneath the stigma, prevents the pollen from falling upon the stigma of the same flower.

The Stigma. This is *the part which receives the pollen.* It is either destitute of an epidermis or covered with a very thin one, secretes a viscid secretion, and is usually more or less roughened or papillose. This structure doubtless has reference to securing the pollen that is conveyed to it and ensuring its germination. In form and character the stigma differs much in different flowers. It may be *terminal*, or located at the apex of the style, or it may be *lateral* or confluent down its side ; it may be *simple* or *lobed ;* it may be *discoid* or flattened and disc-like, *hemispherical*, *globular*, *filiform*, *petaloid*, *plumous* or feathery, *radiate* or rayed like the spokes of a wheel, *stellate* or star-shaped, *cucullate* or hooded, *flabellate* or fan-shaped, *rostrate* or beaked.

The Ovule. The ovules are the small bodies in the ovary, which, after fertilization, develop into seeds. By some botanists they are regarded as homologous with the lobes or teeth on the margin of a toothed leaf, and by others as modified plant hairs. They are usually borne on a definite ovule-bearing portion of the interior of the ovary, called the placenta, but occasionally they occur without order on any portion of the ovary walls.

A complete ovule, Fig. 269, consists of a *nucellus*, or body, two coats, the outer called the *primine* and the inner the *secundine*, and a *funiculus* or *podosperm*, the stalk of the ovule. The coats do not completely enclose the nucellus, but a little opening for the reception of the pollen tube is left at the apex. This opening is called the *micropyle* or foramen. The base of the ovule, where the coats are attached to each other and to the nucellus, is called the *chalaza*. The point of attachment of the funiculus to the rest of the ovule is called the *hilum*. In some ovules the funiculus grows fast to the ovule for a portion of its length, as in Figs. 272 and 273. The adherent portion is called the *rhaphe*.

It is frequently the case that some parts of the ovule are wanting. The funiculus is often absent, and the ovule is then said to be *sessile;* in *gymnospermous* plants. like the Pine and Fir, only one of the coats is usually present; and in the Mistletoe and its allies, both coats are wanting.

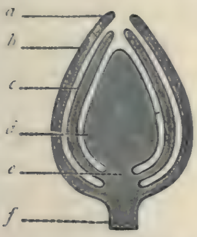


Fig. 269.—Longitudinal section of an ovule, showing its various parts; *a*, micropyle; *b*, primine; *c*, secundine; *d*, nucellus; *e*, chalaza; and *f*, funiculus or podosperm.

It is sometimes of importance to observe the position of the ovule in the ovary. It is *erect*, when it rises upright from the bottom of the cavity of the ovary; it is *ascending*, when it rises obliquely from near the bottom; it is *horizontal*, when borne on the side of the ovary wall and pointing in a transverse direction; it is *pendulous*, when directed obliquely downward from near the top of the cavity, and it is *suspended*, when hanging from the very top of the cavity.

The shape of the ovule itself is also to be regarded. An *atropous* or orthotropous ovule is one that is straight, and has the hilum and micropyle at opposite ends, as in Fig. 270; a *campylotropous* ovule is one whose body is bent so that the hilum and micropyle are approximated, as in Fig. 271; an *amphitropous* ovule is one that is partly inverted; that is, one that has

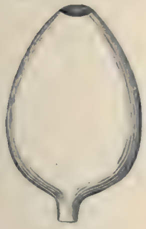


Fig. 270.

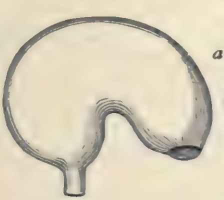


Fig. 271.

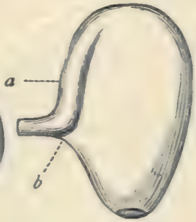


Fig. 272.

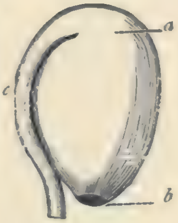


Fig. 273.

Fig. 270.—An atropous or orthotropous ovule.
Fig. 271.—A compylotropous ovule.
Fig. 272.—An amphitropous ovule; *a*, rhaphe; *b*, hilum.
Fig. 273.—An anatropous ovule; *a*, chalaza; *b*, micropyle; and *c*, rhaphe.

the funiculus located near the middle of the straight body of the ovule and pointing in a direction at right angles to it, as in Fig. 272; and an *anatropous*, or inverted ovule, is one whose chalaza is at one end, and hilum and micropyle adjacent to each other at the opposite end, as in Fig. 273. In the latter two kinds, the funiculus is adherent to the body of the ovule for a portion of its length; it is this adherent portion that is called the rhaphe. Inverted, or partly inverted, ovules are much more common than straight or bent ones.

PRACTICAL EXERCISES.

Study the flowers of the following plants with reference to the pistils: The Poppy, the Stramonium, the Lily, the Pumpkin, the Rose, the Hollyhock, and the Indian Corn. Determine (1), the parts of the pistil present in each case; (2) whether the pistils are apocarpous or syncarpous, and if the latter, state the degree of union; (3) the placentation of the ovary—that is, whether it is parietal, axile or free-central; (4) to what degree, if at all, the ovary is adherent to adjacent organs; (5) the position and shape of the style; (6) the position and shape of the stigma; (7) the arrangement of the ovules in the ovary; and (8) the shapes of the ovules.

In studying the ovules and placentation, the student should make careful longitudinal and transverse sections of the ovaries with a very sharp knife; they may then usually be studied satisfactorily by means of a good lens, but in some cases, where the ovules are quite small, the compound microscope will be indispensable.

CHAPTER XII.—POLLINATION AND FERTILIZATION.

Pollination. This consists in *the conveyance of the pollen from the stamen to the pistil in such a manner as to produce fertilization, or cause the setting of seed.* Until recent years it was generally supposed that most flowers possessing both stamens and pistils were self-fertilizing—that Nature's design in placing the two organs so near together was to make sure of bringing the pollen in contact with the stigma of the same flower. There are, indeed, some instances in which this is the case, and such flowers, since they are habitually self-fertilizing, are called *autogamous.* But flowers of this kind are now known to be comparatively rare, and cross-fertilization, or *allogamy*, that is, the fertilization of the pistil by pollen derived from another flower, is the general rule. Most flowers are so constructed that external agencies of various kinds are utilized for this purpose, and the appliances by means of which the result is secured and close-fertilization prevented, are sometimes very elaborate and wonderful. Even where the anther and the stigma are in the closest juxtaposition in the same flower, the pollen, in many cases, is effectually prevented from reaching the stigma, while the arrangements at the same time are such as to insure its being brought to it from another flower. It is evident from the pains Nature has taken to secure the result, that some great advantage must accrue to the plant or its offspring from allogamy, and this has also been proved to be the fact by careful and extended experiments. It is proved that there are some plants that utterly refuse to set seed when supplied with only their own pollen, that there are others which greatly prefer pollen from another plant, and refuse to utilize their own when that from another of the same species is placed upon the stigma, and it is proved that in the great majority even of those plants which are capable of close-fertilization, stronger, hardier and more numerous offspring result from cross-fertilization.

The external agencies utilized by the plant to bring about cross-fertilization are chiefly the wind and insects. Humming-birds, and some other species of birds that habitually visit flowers, are occasionally of service, and in the case of some aquatic plants currents are made use of; but these agencies are comparatively unimportant.

Flowers whose pollination is effected by means of the wind are called *anemophilous*. Such flowers differ markedly in appearance and structure from those in which insects are the agents. They are usually provided with stigmas that expose a good deal of surface to the wind; they produce great abundance of dry, powdery pollen; they are without showy floral envelopes; they are without nectar, and they are destitute of perfume. Frequently, also, but not always, the pistils and stamens are in separate flowers, thus making self-fertilization impossible.

The difference between the extent of surface exposed by the stigmas of anemophilous flowers and those pollinated by insect agency will be seen by reference to Figs. 274 to 279, inclusive. The three figures at the left represent, respectively, the pistils of

Wheat, Juncus acutiflorus and Hemp, all anemophilous, and the three at the right, the pistils of the Tobacco, Foxglove and Centradenia floribunda, all of which are pollinated by insect agency. The enormous quantities of fine pollen produced by such anemophilous plants as the Pines and Indian Corn, and the great distances to which it is wafted, are facts familiar to every observing mind. The Oaks, Poplars, Birches, Walnuts, Grasses, Sedges, Plantains, Nettle and Hop are examples of plants of this kind.

Flowers which are cross-fertilized by the agency of insects are called *entomophilous*. They include all those with showy calyx, corolla or bracts, all perfumed flowers, all nectar-bearing, and all irregular flowers. The gay colors and perfumes are to attract the attention of insects, the nectar to reward them for their services, and the irregularities are adaptations of the flower to their visits, the character of the adaptation being such as to render cross-fertilization by their aid more certain. Bright colors and perfume sometimes go together, and the flower offers a double attraction to the insect visitor; but more commonly highly colored flowers are not odorous, or are but faintly so, and conversely, highly odorous flowers are commonly not showy. Flowers with corollas of some shade of red or blue are usually

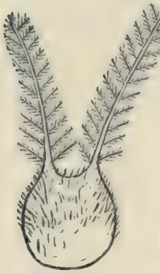


FIG. 274.

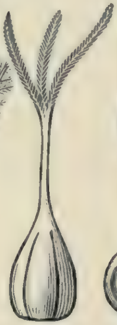


FIG. 575.

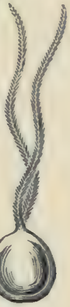


FIG. 276.

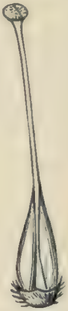


FIG. 277.

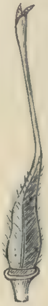


FIG. 278.

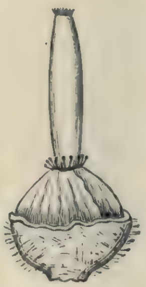


FIG. 279.

FIG. 274.—Pistil of Wheat, showing a pair of long feathery stigmas.
FIG. 275.—Pistil of Juncus acutiflorus, showing three elongated, hairy stigmas.
FIG. 276.—Pistil of Hemp, with two slender and much elongated, hairy or papillose stigmas.

All anemophilous.

FIG. 277.—Pistil of Tobacco, with small, somewhat two-lobed, capitate stigma.
FIG. 278.—Pistil of Digitalis, showing small, two-lobed stigma.
FIG. 279.—Pistil of Centradenia floribunda (enlarged), showing small papillose stigma.

All entomophilous.

visited by diurnal insects, while those with white or light-yellow corollas are often visited by moths and other insects that fly at dusk, these colors being more readily perceived in the dim light than others. It is by no means true. however, that all white flowers are fertilized by crepuscular insects.

Even the stripes or lines found on corollas are significant; they point to the locality in the flower where the nectar is secreted, and serve the purpose of guiding the insect thither.

The disagreeably odorous flowers are attractive to some insects no less than the pleasantly odorous ones are to others. The giant flower of Rafflesia, for instance, has a carrion-like odor and a beefy appearance which attract swarms of carrion-flies that are deceived into depositing their eggs upon it, dooming their maggot progeny to starvation; in the process, however, they are likely to bring pollen from another flower and deposit it on the stigma. Some flowers which are visited by night-flying insects withhold their perfumes by day, but dispense them freely at night, as in the case of the night-blooming Jasmine (Cestrum). Some flowers, also, that are cross-fertilized by day-flying insects, close at night, doubtless, in some instances at least, to prevent the wastage of nectar and pollen by insects that could not be of service to the plant.

We may briefly summarize, as follows, the different means by which self-fertilization is prevented among entomophilous plants.

(1) *By the separation of the flowers into staminate and pistillate forms, that is, by diclinism.* Diclinous plants are of two kinds: *monœcious*, as the Begonia, where both kinds of flowers occur on the same plant, and *diœcious*, as most Willows, where the male and female flowers occur on different plants.

(2) *By dichogamy*, or the maturing of the male and female organs at different periods. This, occurring in flowers which possess both stamens and pistils, is the same in its effects as though the male and female organs were in separate flowers. There are two kinds of dichogamy, one in which the stamens first mature and then afterward the pistils, and the other in which this order is reversed and the pistils are the first to mature. Flowers of the former kind are called *proterandrous*, or protandrous, while those of the latter are called *proterogynous* or proto-

gynous. The Pinks, Gentians, many of the Compositæ, Umbelliferæ and Labiatæ, the Geranium, Mallow, and many Lobelias and Campanulas are proterandrous. Figures 280 and 281 represent flowers of the common Pink, in different stages of development; in the former the stamens are ripe, and shedding their pollen; while in the latter and older flower they are past maturity and have withered, the expanded stigmas taking their place. It is evident that an insect which has visited the younger flower, and become dusted with its pollen, could hardly fail, when visiting the older, to deposit some of it on the stigmas.

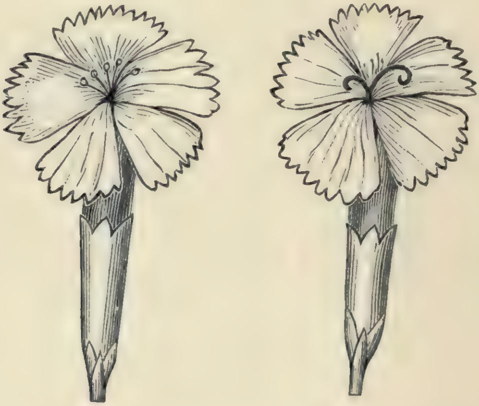


FIG. 280. FIG. 281.

FIG. 280.—Flower of Pink in the earlier or staminate stage of development.
FIG. 281.—Flower of Pink in the later or pistillate stage of development.

Figs. 282 and 283 represent the proterandrous flowers of the Great Willow Herb, Epilobium angustifolium. The mode of cross fertilization is analogous to that of the Pink just described.

In Fig. 282, the stamens, which are ripe and protrude from the corolla, stand in such a position that an insect visiting the flower for its nectar must touch them and receive some of their pollen, but the style, crowned by the not yet unfolded stigma lobes, is curved back out of the way. Later, as shown in Fig. 283, the stamens, having shed all their pollen, wither and curve back upon the petals, while the style straightens out and the stigmas unfold, occupying about the same position as the anthers did before. It is clear that here, as in the Pink, an insect flying from a flower in the earlier to one in the later stage of development, will be likely to transfer pollen to the latter flower and fertilize it.

Proterogynous flowers are much less common, though interesting instances of them are found in the Birthwort, in Arum, in Scrophularia nodosa, and in some other plants. Fig. 284 is a diagram of the inflorescence of the Arum. The large enveloping spathe is contracted near its middle, leaving but a narrow passageway to the cavity below, which encloses the separate masses of staminate and pistillate flowers. This passage-way is obstructed by stiff hairs, which point downward. These, being flexible at their base, are readily bent downward and afford but a slight obstacle to the entrance of insects, but they are not so easily forced upward from below, because pressure in that direction brings the distal ends of the hairs into contact with the side walls of the tube. The insects which enter are, therefore, imprisoned. The pistillate flowers are clustered at the base of the spadix, and reach maturity considerably earlier than the staminate ones which are clustered above them. After the stigmas have passed maturity, a drop of nectar is secreted in the bottom of the tube to compensate the flies for their imprisonment; the anthers, now ripened, shed their pollen in abundance; the insects' bodies become thoroughly dusted with it; and, lastly, the hairs that prevented their exit, wither, permitting them to fly away to some other inflorescence of the same kind, carrying with them the fertilizing pollen.

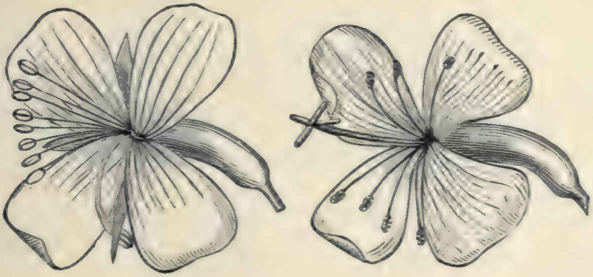


FIG. 282. FIG. 283.

FIGS. 282 and 283.—Staminate and pistillate stages, respectively, of flowers of Epilobium angustifolium.

Figs. 285 and 286 represent the pistillate and staminate stages, respectively, in the development of the flower of Scrophularia nodosa. The nectar is secreted in the base of the tube. In the younger or pistillate stage the stigma is exposed at the entrance, in such a position that a visiting insect must come into contact with it in order to reach the nectar; the unripe stamens are bent back out of the way. In the older or staminate stage the stigma lies withered on the lip of the flower, while the four anthers, now ripe, are exposed in the throat, dusting with pollen the insect that visits the flower. It is evident that a bee flying from an older to a younger flower must necessarily effect the cross-fertilization of the latter.

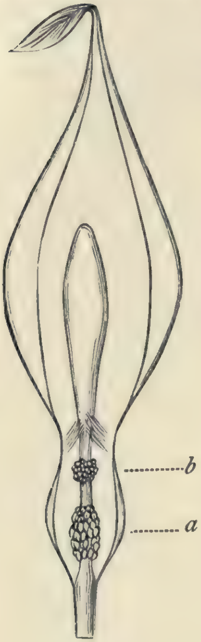


FIG. 284.

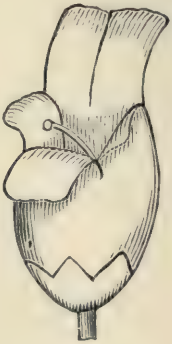


FIG. 285.

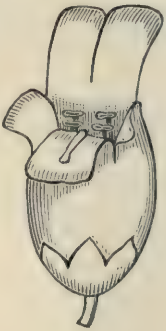


FIG. 286.

FIG. 284.—Diagram of the inflorescence of Arum maculatum. The spathe is contracted near its middle, and the passage-way obstructed by stiff hairs which point downward. These, being flexible at their base, permit the ingress, but not the egress, of insects. The pistillate flowers are clustered at *a*, on the base of the spadix, while the staminate flowers are above at *b*. The former mature first, and after the pollen is shed, the hairs wither, permitting the pollen-dusted insects to escape.

FIGS. 285 and 286 represent the pistillate and staminate stages, respectively, of the flower of Scrophularia nodosa. When the flower first opens, the stigma is mature, and in the way of a visiting insect; after this has withered, the stamens curve upward, and the now ripened anthers occupy a position similar to that previously occupied by the stigma.

(3) *By the prepotency of foreign pollen.* It has already been stated that in some cases pollen from the same flower is entirely ineffective. This has been proved to be the case with Lobelia fulgens, Verbascum nigrum, Primula verticillata, and some other plants.

But even in cases where the flowers are capable of self-fertilization, the pollen from other plants is commonly more effective than their own; and, as showy or nectar-bearing flowers are almost constantly visited by insects, the chances are that cross-fertilization will usually be effected.

(4) *By heteromorphism*, or by the existence within the limits of the same species of flowers of different kinds. In some cases there are two different kinds of flowers,—one with short stamens and long styles, and the other with long stamens and short syles.

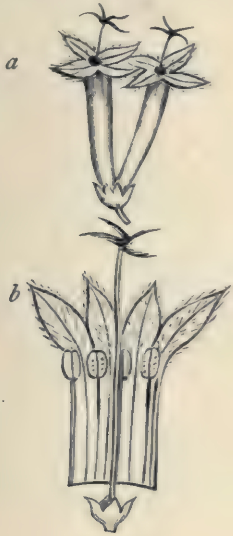


FIG. 287.

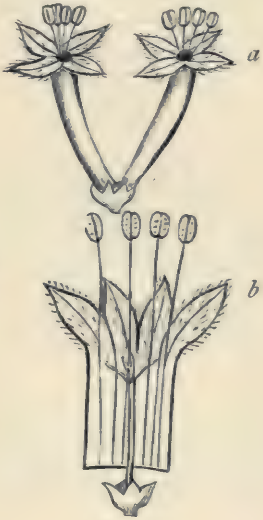


FIG. 288.

FIG. 287.—*a*, two long-styled flowers of Mitchella repens. *b*, the tubular corolla of one laid open so as to show the stamens.

FIG. 288.—*a*, two short-styled flowers of same species; the styles are concealed in the tube of the corolla, while the stamens protrude. *b*, one of the corolla-tubes laid open to show the stigmas.

Such flowers are called *dimorphous*. Figs. 287 and 288 represent, respectively, the long-styled and short-styled flowers of Mitchella repens. The flowers occur in pairs, usually grown together, more or less, at the base, as shown in the figures *a*, *a*. It will be seen that the stigmas of the left-hand pair stand at about the same level as the anthers of the right-hand one. The two different kinds of flowers invariably occur on different plants of the same species. The lower figures, *b*, *b*, represent a flower of each kind, with the corolla tube laid open to show the relative arrangement. It will be seen that a bee visiting one of the short-styled flowers will have her head dusted by pollen from the long stamens as she reaches to the bottom of the cup for the nectar, and that in passing to one of the long-styled flowers she will bring the same parts in contact with the stigmas, and therefore probably deposit pollen upon them. At the same time, also, her proboscis is brought in contact with the short stamens in the tube, and its middle portion dusted with the adhesive pollen. If now again she visits a short-styled flower, some of this pollen will in all probability be left upon the stigma.

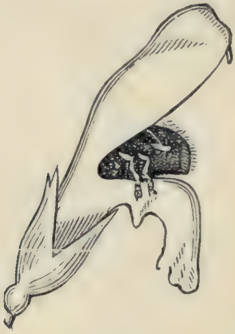


FIG. 289.

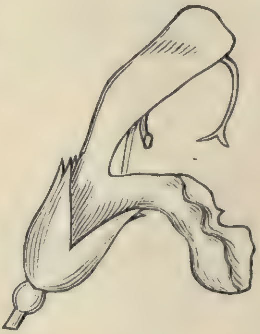


FIG. 290.

FIG. 289.—Flower of the common Sage, in the staminate stage, visited by a bee. The fertile anther lobes are seen in contact with the insect's body, while the stigma is well out of the way, barely projecting from the upper lip of the corolla.

FIG. 290.—Flower of the Sage in the pistillate stage, when the stamens have withered and the style lengthened, so as to occupy a position similar to that of the fertile anther lobes in the previous figure.

In some other cases, as in Lythrum salicaria, there are flowers of three different kinds, long-styled, mid-styled, and short-styled ones, which constitute a very effective means of cross-fertilization by insect agency. Such flowers are called *trimorphous*.

(5) *By special contrivances.* Many of these are exceedingly elaborate and wonderful. The flower of the common Sage is an illustration of one of them. The flowers are proterandrous, and are pollinated by bees. Fig. 289 represents one in the staminate stage visited by a bee; the stigma is out of the way, nearly concealed under the arching upper lip of the corolla, while the anther-lobes are in contact with the back part of the insect's body as she sips the nectar. Fig. 290 represents a flower of the

same plant in the pistillate stage, when the anthers have discharged their pollen and the style has lengthened, unfolding its stigmatic lobes and occupying such a position as to come in contact with the back of the insect when she enters the flower.

The flower has two stamens, separately represented in Fig. 291, inserted in the throat of the corolla in such a position that the insect, in order to reach the nectar, must pass between them. Each anther has a long, curved connective, which is pivoted near its middle to the apex of the filament. One lobe, the upper one in the undisturbed flower, is fertile, and the other sterile. Fig. 291 represents them as they are in their normal position, and Fig. 292 as they are when a bee passes between them, butting her head against the sterile lobes, pushing them forward and upward, and turning the fertile lobes backward and downward. It is evident that the insect visiting the flower in its staminate stage will get the back and upper portion of her hairy body dusted with pollen from contact with the fertile lobes, and in flying away to a flower which is in the pistillate stage, will bring the same part of her body into contact with the stigmas.

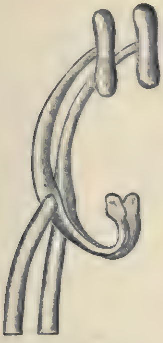


FIG. 291.

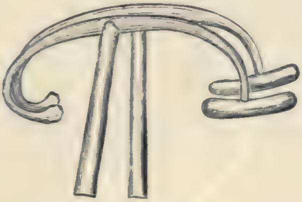


FIG. 292.

FIG. 291.—Position of stamens of Sage, when undisturbed.

FIG. 292.—Position of anthers, when a bee passes between the stamens to reach the nectar.

Another interesting instance among the hundreds that might be mentioned occurs in Habenaria ciliaris, one of our most beautiful orchids. Fig. 293 represents one of the flowers of this plant. In the centre of it is the column of combined pistils and stamens, *a*. The stigma lies centrally between the anthers, each of which produces a pollinium, which is club-shaped in form, and has at its lower end a sticky disc, as represented in Fig. 294. The delicately fringed lip is connected at its base with the long, tubular nectary, *b*, Fig. 193, which contains the honey secretion. The flowers are visited by butterflies, whose long tongues enable them to probe the bottom of the tube. In this process the visiting insect squeezes the thick basal portion of his tongue between the sticky discs of the pollinia, which adhere firmly, and are withdrawn from the anthers when he flies away. The pollinia, when first withdrawn, stand out nearly at right angles to the insect's tongue, but after a few moments, by a drying process which they undergo, they bend obliquely downward and somewhat inward, so that when the next flower is visited, they are brought into contact with the sticky stigmatic surface, and some of the pollen is almost inevitably deposited upon it. By flying thus from flower to flower, a considerable number may be fertilized before finally the pollinia are brushed off, or their pollen exhausted.

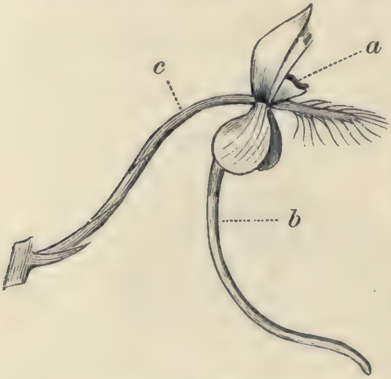


FIG. 293.

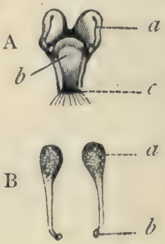


FIG. 294.

FIG. 293.—Flower of Habenaria ciliaris, with three rounded sepals, two strap-shaped petals which are fringed at the apex, a fringed lip with the base of which is connected a long, tubular nectary, *b*; a column, *a*, consisting of a stigma depressed between two anther-lobes, each of which contains a pollinium. *c* is the ovary of the flower. The flower is magnified about two diameters.

FIG. 294, A and B.—A, Column of combined stigma and stamens, separated from the flower and more highly magnified. *a*, one of the anthers, the slit showing where the pollinium has been withdrawn; *b*, the stigma; *c*, opening into the nectary at the base of the labellum. B, The two pollinia still more highly magnified; *a*, the mass of agglutinated pollen grains; *b*, the sticky disc at the opposite end of the pollinium.

While, as has been stated, cross-fertilization is the law, there are a few remarkable instances in which flowers appear to be constructed with special reference to self-fertilization. Some Violets and Polygalas, for example, produce, besides showy flowers that are visited by insects, others that are inconspicuous, closed, and often partly concealed beneath the ground, so that insects cannot penetrate them, and in which the pollen falls directly upon the stigma and fertilizes it. Such flowers produce seed abundantly, and yet there is the closest of in-and-in breeding. They appear to be a contrivance by means of which the plants are able to produce a greater multitude of seeds with a less expenditure of force than by the production of an equal number of the ordinary flowers. They seem to multiply in this way as other plants do by means of bulblets or tubers, while the occasional crossing which occurs by means of the showy flowers serves to keep the stock vigorous.

It does not come within the scope of this work to treat this subject more extensively, but those who are interested in it, and wish to pursue it further, should read some or all of the following works: Darwin's "Cross and Self Fertilization in the Vegetable Kingdom;" Sir John Lubbock's "British Wild Flowers in Relation to Insects;" Mueller's "The Fertilization of Flowers," and the chapter in Prof. Gray's "Structural Botany" which relates to this subject.

II.—Fertilization. By Fertilization is meant *the process which takes place subsequent to the deposit of the pollen on the stigma, resulting in the union of the contents of the two reproductive cells, the pollen-cell and the germ-cell.*

The pollen-grain, conveyed by the wind, by insects, or by some other means, is securely held and stimulated to germination by the adhesive secretion of the stigma on which it is deposited, and it soon forms a pollen-tube which readily finds its way between the easily separable cells of the loose interior tissues of the style, or through the canal in the latter, if there be one, to the interior of the ovary, and enters the micropyle of the ovule, as shown in Figs. 295 and 296. As many pollen-tubes will be required as there are ovules in the ovary, every separate ovule requiring one for its fertilization.

The time that it takes for the pollen-tube to reach the ovule and effect its fertilization varies greatly in different plants. In some it occupies only a few hours, while in others it may require weeks, or even months, as in the Orchids.

In the meanwhile, the ovule is preparing to receive the fertilizing influence of the pollen. This preparation consists in the formation of a large cell in the nucellus of the ovule, called the *embryo-sac.* Sometimes the embryo-sac is so strongly developed as to entirely replace the nucellus, as in some Orchids and in Monotropa hypopitys; in other instances, its upper end bursts through the tissues of the nucellus and either lies at the upper surface of the latter, or protrudes beyond it. The latter is the case with the commonly cultivated green-house plant, Torenia Asiatica. Oftener, it is more or less deeply buried in the tissues of the nucellus. It is, however, always of large size, and thick-walled as compared with the other cells of the nucellus.

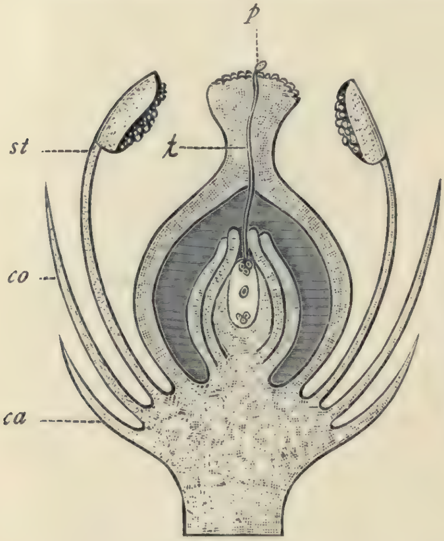


FIG. 295.

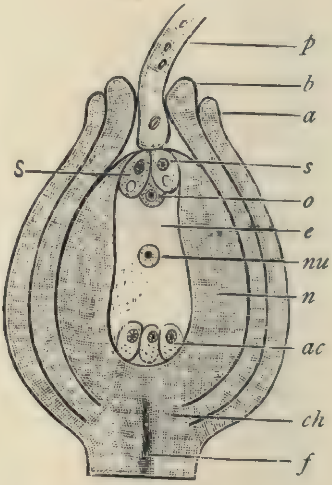


FIG. 296.

FIG. 295.—Diagram of flower in vertical section to show fertilization of ovule: ***ca,*** **calyx;** ***co,*** **corolla;** ***st,*** **stamen;** ***p,*** **pollen grain sending tube,** ***t,*** **down through the tissues of the style and into the micropyle of the ovule. In the nucellus of the ovule is seen the embryo-sac with the synergidæ, oösphere, antipodal cells and nucleus.**

FIG. 296.—Diagram representing an ovule in the process of fertilization: *f,* funiculus of the ovule penetrated by a spiral vessel; *ch,* chalaza; *a,* outer integument, or primine; *b,* inner integument, or secundine; *p,* end of pollen-tube that has penetrated to the nucellus, *n; e,* embryo-sac; *nu,* nucleus of embryo-sac; *s,s,* the two synergidæ; *o,* the oösphere; and *ac,* the antipodal cells.

At the upper or micropylar end of the embryo-sac is formed the *egg-apparatus*, consisting of two cells called the *synergidæ*, and another cell called the *oösphere* or *germ-cell*, which, after fertilization, is destined to develop into the embryo. The synergidæ each have a *vacuole* or transparent sap-cavity at the lower end, and a nucleus located well toward the upper end; the oösphere, on the other hand, has its vacuole above and its nucleus below. It usually also occupies a somewhat lower position in the embryo-sac (see Fig. 296, *o*). At the lower or opposite end of the sac are formed three cells, called the *antipodal cells*, while somewhere in the clear space between the latter and the *egg-apparatus*, a nucleus may be discerned. In many cases there is formed on the upper part of the synergidæ a kind of spongy cap, consisting of cellulose, which is traversed by delicate pore-channels containing albuminous matter. This cap fills a perforation in the wall of the embryo-sac, forming a kind of stopper to it; it is technically called the *filiform apparatus* (see Fig. 297, *f*).

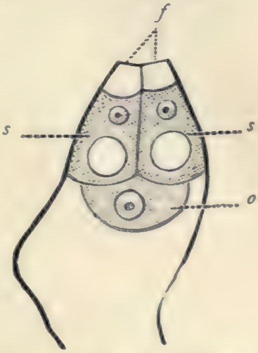


FIG. 297.—Upper part of embryo-sac of Torenia Asiatica, after Strasburger. *s*, *s*, the two synergidæ capped by the filiform apparatus *f*; *o*, the oösphere.

The pollen-tube is guided to the micropyle, partly by various mechanical contrivances, such as by papillæ on the placenta, by the position of the funiculi, etc., and partly, also, as it nears its destination, by the stimulating influence of a fluid which escapes from the synergidæ through the filiform apparatus. Sometimes the embryo-sac is penetrated by the pollen-tube—the ovules of Canna afford an illustration of this kind; but more commonly it merely comes into contact with its surface, or with that of the filiform apparatus. A transference of the fertilizing substance then takes place, which is evidenced by important changes in one, or sometimes both, of the synergidæ. Their contents become turbid, and then disintegration begins. These changes are followed by remarkable ones in the oösphere. It becomes invested in a delicate cell-wall; a second nucleus, smaller than the first, makes its appearance in the interior, and this, after a little, unites with the one originally present. Soon after this, cell-division takes place, and the oöspore, as it is now called, begins to develop into an embryo. Some of the successive stages in this development are roughly illustrated in the diagrams, Figs. 298 to 301, inclusive. At first, cell-division takes place only in one plane, and a chain or linear series of cells, technically called the *suspensor*, or *pro-embryo*, is formed. Then the terminal member of this chain begins to divide in different planes, forming a mass of cells. This latter is the real beginning of the embryo, and, as cell-division proceeds, the mass gradually becomes differentiated into the various organs of the embryo, a rudimentary root, a rudimentary stem and rudimentary leaves becoming recognizable. It is to be observed that the root end, or radicle, always points toward the micropyle of the ovule.

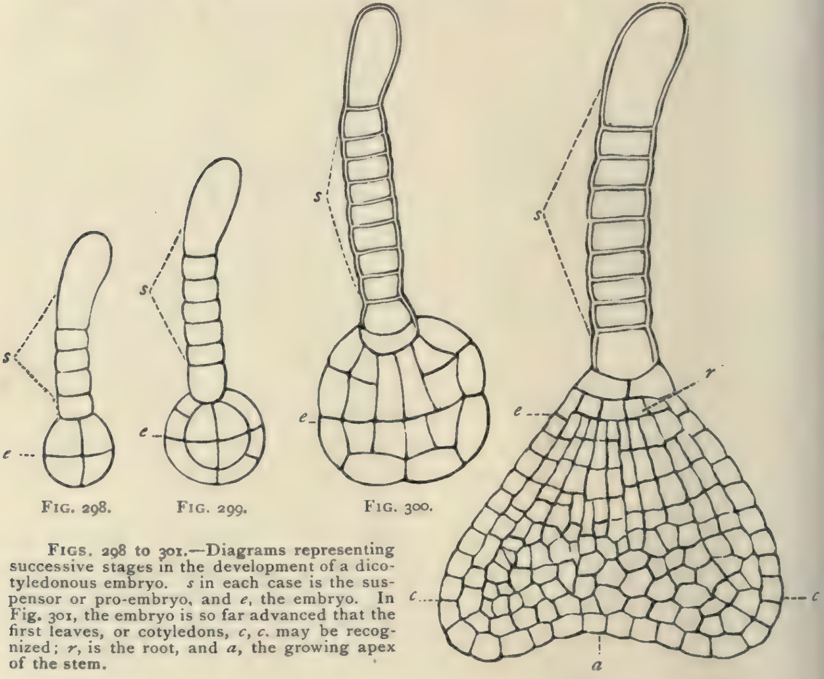


FIG. 298. FIG. 299. FIG. 300.

FIGS. 298 to 301.—Diagrams representing successive stages in the development of a dicotyledonous embryo. *s* in each case is the suspensor or pro-embryo, and *e*, the embryo. In Fig. 301, the embryo is so far advanced that the first leaves, or cotyledons, *c*, *c*. may be recognized; *r*, is the root, and *a*, the growing apex of the stem.

FIG. 301.

While the embryo is forming, other important changes are taking place in the embryo-sac. As soon as the oöspore commences its division, or sometimes even before that, the formation of endosperm begins. The nucleus of the sac first divides and, in some instances, forms a great mass of nuclei which line the wall of the sac, as shown in Fig. 302. Afterwards, these nuclei become perfect cells by the development of cell-walls, and the further growth of the endosperm now goes on by cell-division, which proceeds from without inwards. This is the more usual process. Sometimes, however, the first division of the nucleus results in the formation of two perfect cells, and the development of the endosperm takes place from the very first by cell-division, and not by nuclear division. In most cases, the embryo-sac enlarges very materially after fertilization and during the formation of the endosperm. Commonly, also, the cells of the latter and of the embryo completely fill it when the seed is mature, but there are instances, of which the Cocoa-nut affords a conspicuous example, where only the peripheral portion of the interior of the sac becomes cellular, while the interior remains fluid. The so-called "milk" in the Cocoa-nut, is the portion of the cavity of the embryo-sac which has failed to become cellular, while the "meat" that surrounds it is the endosperm.

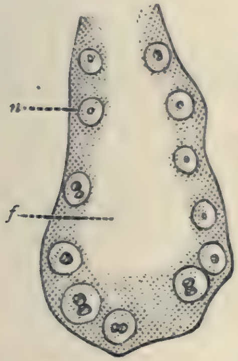


FIG. 302.—Diagram of the lower portion of the embryo-sac of the Pansy Violet after fertilization, showing the development of the endosperm. *n*, one of the nuclei buried in granular protoplasm: *f*, fluid interior of embryo-sac.

In most cases, as the embryo-sac and its contents develop, the cellular tissue outside it in the nucellus is absorbed and disappears; but in some instances it remains or even increases in quantity, and is termed the *perisperm.* In the seeds of Canna, all of the nutritive tissue exterior to the embryo and within the seed-coats is perisperm. The seeds of the Peppers contain much perisperm and a comparatively small quantity of endosperm. Its use to the plant is the same as that of the endosperm, namely, to supply food to the germinating embryo. The endosperm that is formed does not always remain until the seed is ripened, but not infrequently, as in the Melon and Bean, it is completely absorbed by the growing embryo, and all within the seed-coats comes to consist of embryo. In a few cases also an endosperm is never developed at all. Beside the changes which take place in the interior of the nucellus as the result of fertilization, very important ones also occur outside of it. The ovary always increases in size; sometimes to a remarkable extent, and equally remarkable changes take place in the character and consistence of its walls. Compare, for instance, the ovary of the apple in flower with the ripened fruit, or the pistil of the cherry blossom with a ripened cherry. Moreover, organs exterior to the ovary feel the influence of the process. Even pollination is sufficient, in many cases, to cause the stamens and corolla to wither and fall away before the pollen-tubes have had time to reach the ovules. It is well known that the period of blossoming may be greatly prolonged in most flowers, if the pollen be prevented from gaining access to the stigmas. The results of the fertilization also often affect organs as far removed from the ovule as the calyx and receptacle, and even the bracts beneath the flower. Indeed, the influence is even more far-reaching than this, for the enormous development which the fertilized pistil undergoes, shows that all the nutritive processes in the plant must be more or less deeply affected.

Practical Exercises.

1. Compare the flowers of the Plantain, Indian Corn, Wheat, Timothy Grass and Hazel, all of them anemophilous, with the flowers of the Geranium, Pink, Apple, Buttercup, Poppy, or other entomophilous flowers, and note (1) the difference between the stigmas of the two groups as regards the extent of surface which they expose; (2) the difference as to the abundance and character of the pollen; (3) the difference in showiness, presence or absence of perfume, etc. (4) Observe in the Geranium whether the flower is proterandrous, proterogynous, or whether the maturing of the stigmas and anthers is simultaneous. (5) Observe different flowers of the Pink, and note the difference between the staminate and pistillate stages. (6) Ascertain whether the anthers of the Buttercup dehisce extrorsely or introrsely, and state, if you can, what relation the facts you discover bear to the cross-fertilization of the plant.

2. Examine the flowers of the common Blue Flag; note the position of the nectar, the relative position of the anthers and stigmas, which way the anthers face, and the mode of their dehiscence, and determine, if you can, the manner in which cross-fertilization is effected.

4. Examine the flowers of the common Barberry; observe the relative arrangement of the stamens and petals; observe the structure of the anthers, and their mode of dehiscence; by means of a pin irritate them slightly at the base, and observe the movement; note the shape of the stigma, and the position of the nectar secretion; if possible, observe the flower while it is being visited by an insect, and then explain its adaptations to cross-fertilization.

Other interesting flowers to study for the same purpose are those of the Milkweed, the Cypripedium, the Pea, and the common Mallow.

5. For cleistogamous flowers examine late in summer the runners concealed underneath the leaves of Viola blanda, or of the English Violet (Viola odorata). Examine carefully their structure, and observe in those which have fruited the number of seeds produced.

For the same purpose also study the cleistogamous flowers of Polygala polygama, and compare them carefully with the showy flowers of the same plant.

As the study of the fertilization of the ovule is a matter of considerable difficulty, and requires the use of high powers, it should be deferred until the student has acquired the requisite skill in the use of the microscope.

CHAPTER XIII.—THE FRUIT AND SEED.

I.—The Fruit.

The fruit consists essentially of the ripened pistil or pistils, but it may also include other organs which grow fast to it in the process of their development.

Its structure, in a general way, resembles that of the pistil or gynæcium from which it is derived. The modifications which it undergoes in its development, in many cases at least, have reference to the dispersion of the seeds when they are ripened.

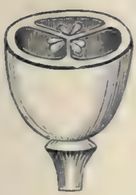


Fig. 303.

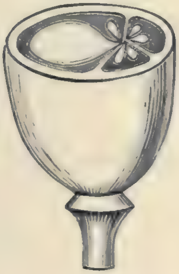


Fig. 304.

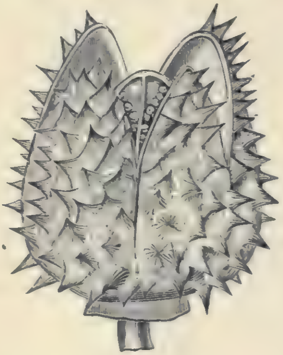


Fig. 305.

Fig. 303.—Ovary of Buckeye when in Flower, cut transversely, showing three loculi and two ovules in each loculus.
Fig. 304.—Ovary of Buckeye, cut transversely at a later stage of development, showing one ovule strongly developed, while the others have ceased their growth.
Fig. 305.—Capsule of Stramonium.

The kinds of modifications that may take place are chiefly the following:

(1) The number of loculi, or cells in the ovary, may decrease in number, as in the fruit of the Oak, which in flower is three-celled, but in ripening becomes one-celled. The similar case of the fruit of the Buckeye is illustrated in Figs. 303 and 304. The former figure represents a cross-section of the pistil at the time the flower is in full blossom when it contains three cells with two ovules in each cell, and Fig. 304 represents the same at a considerably later period of development, showing the almost complete abortion of two of the cells and of all the ovules but one.

(2) An increase in the number of loculi sometimes takes place from the formation of false partitions, as illustrated in the capsule of Stramonium, which in flower is two-celled, but in fruit becomes four-celled. Fig. 305.

(3) Alterations in the character of the surface may take place, as is also illustrated in Stramonium, whose pistil, when in flower, has only a soft, hairy covering, but in fruit is densely covered with sharp prickles; or in the Maple, whose pistil in flower is merely two-lobed, but, in fruit, develops on each lobe a prominent wing-like appendage, as shown in Fig. 306.

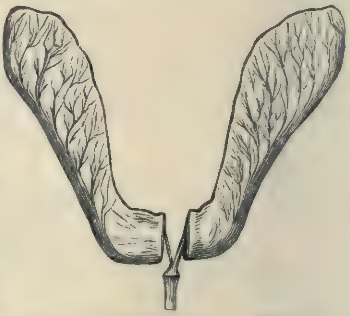


Fig. 306.—Double Samara of Maple.

(4) Alterations in the consistency of the ovary wall may take place. These may be of different kinds: (a) They may become thin and papery, as in the Bladder-senna; (b) hard and bony, as in the pericarp of many capsules; (c) tough and leathery, as in the rind of the Orange and Lemon; (d) hard without and soft within, as in the fruit of the Gourd; (e) soft without and hard within, as in the fruit of the Peach and Cherry; or (f) succulent throughout, as in the Gooseberry and Grape.

(5) Organs external to the pistil, but more or less connected with it, often persist and become a part of the fruit. The calyx of the Wintergreen, for instance, grows fleshy, envelops the capsule, becomes red in color, and constitutes the edible portion of the fruit; in Clematis the style persists, becomes long and

feathery, and serves to waft away the ripened fruit; in the Strawberry the receptacle becomes thick and succulent, and constitutes the edible portion of the fruit, and in the Dandelion and Thistle the modified Calyx-limb, or pappus, renders the fruit buoyant and easily wafted by the wind.

Doubtless the reason why fruits often have conspicuous colors is to render them attractive to birds and other animals that can aid in their dispersion. As the seeds of edible fruits are usually indigestible or difficultly digestible, the fact that the fruits are pleasing to the taste aids the dispersion of their seeds, and secures their deposit under conditions favorable to germination. The hooks and spines which are found on many fruits, or attached to accessory organs, are also means by which plants utilize animals for the dispersion of their seeds.

Dispersion.—The agencies made use of by nature for the dispersion of fruits and seeds may be classified as follows:

(1) *The Wind*, as when they acquire thin and flattened forms, or are provided with membranous expansions called wings, or have a feathery, hairy or parachute-like pappus, or are otherwise rendered light and buoyant.

(2) *Water Waves or Currents*, as in the case of the Cocoa-nut, which, by its structure, is rendered buoyant, and by reason of its possessing a fibrous husk, and a thick, hard shell, is enabled to resist for a long time the action of salt water.

(3) *Hygroscopism.* This consists in the property possessed by some fruits, by which one part either absorbs water more rapidly than another, or parts with it more readily, thus in some cases causing a strain upon and at last a sudden rupture of the pericarp, scattering the seeds, or else giving rise to movements of a different character which are serviceable in placing the fruit or seed in conditions favorable to germination. To hygroscopism is attributable the violent bursting of the large capsules of the tropical Sandbox tree, Hura crepitans, Fig. 307. When the fruit is thoroughly ripe the segments suddenly separate with a loud report resembling that of a pistol, and the seeds are thrown out

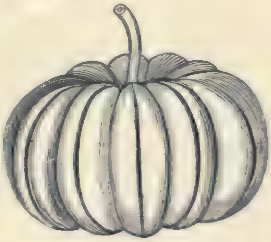


FIG. 307.—Capsule of Sandbox tree, Hura crepitans.

with a force which often projects them to the distance of many yards. The capsules of the well known Touch-me-not, dehisce with violence from the same cause; and by reason of their hygroscopic properties the awns of some grasses twist and untwist as the quantity of moisture in the air changes, and in some instances the motion thus produced is utilized to drive the fruit into the soil. This is the case with the western Porcupine Grass. In some flowerless plants the same property is taken advantage of for the dissemination of the spores. The hygroscopism of the elaters of Equisetum, and some Liverworts, for example, is the means of ejecting the spores from their cases, and so of scattering them to the wind to be sown far and wide.

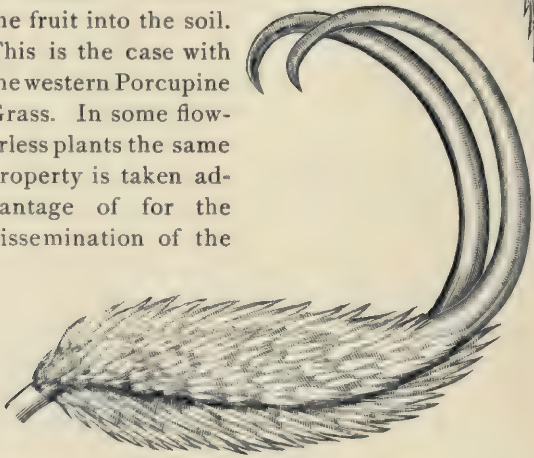


FIG. 308.

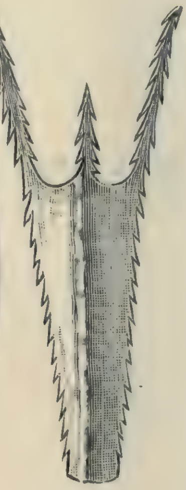


FIG. 309.

FIG. 308.—Fruit of Martynia, considerably reduced. When ripe its beak splits into two sharp, hooked hard horns, by means of which it clings to the tails of cattle and horses, and the seeds are thus scattered.

FIG. 309.—Fruit of Bidens connata, magnified about five diameters.

(4) *Animals.* There are many ways in which plants make use of animals for the dispersion of their fruits and seeds. It has already been suggested that this is one of the reasons why the fruits of some plants have become edible. Birds and frugivorous mammals are certainly, for this reason, among the most important adjuncts in the distribution of plants. By sparrows and squirrels, doubtless, whole forests have been planted. The showiness of many ripe fruits is also unquestionably an impor-

tant aid to the dispersion of their seeds, as it attracts the attention of fruit-eating animals, and causes the fruits to be eaten, or at least to be plucked and tasted. But many fruits and seeds are provided with hooks, spines, barbs, adhesive pericarps, or other means by which they cling to the bodies of animals, and are thus scattered. Fruits of the Burdock, Bidens, Stickseed, Tick-trefoil and Mistletoe are illustrative examples, and many others might be educed. Fig. 308 and 309 represent, respectively, the fruits of species of Martynia and Bidens.

Classification of Fruits.—Although the following scheme of classification does not claim completeness, it includes the most important forms of fruits, and for practical purposes will be found convenient.

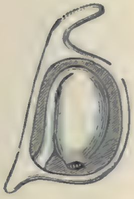


FIG. 310.

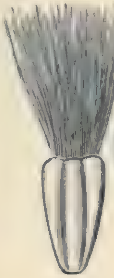


FIG. 311.

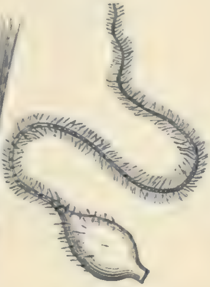


FIG. 312.

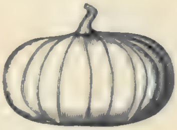


FIG. 313.

FIG 310.—Superior achenium of Ranunculus, with portion of ovary wall removed to show internal structure.
FIG. 311 —Inferior achenium of Sow Thistle.
FIG. 312.—Caudate achenium of Clematis.
FIG. 313.—Utricle of Chenopodium.

They are primarily divided into two groups, those which are the product of a single flower, and those which are the product of a flower cluster.

The former kind are subdivided into those which are the product of one pistil (either apocarpous or syncarpous), and those which are the product of more than one. The former of these subdivisions is divided into *indehiscent* forms, or those which do not split open when ripe, and *dehiscent* forms, those which do. The most important of the indehiscent forms are the following:

(1) The *Akene* or *Achenium*. This is a one-seeded, dry, hard, seed-like fruit, like that of the Ranunculus, shown in lon-

gitudinal section in Fig. 310. The akene may either be *superior*, or free from an adhering calyx, as in the above example, or it may be *inferior*, that is, having the calyx closely adherent, as in the fruit of the Sow Thistle and other Compositæ, Fig. 311. Fig. 312 represents the caudate or tailed achenium of Clematis.

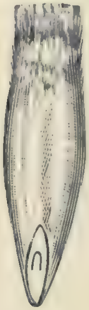


FIG. 314.

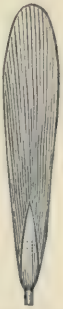


FIG. 315.

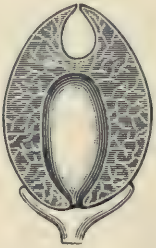


FIG. 316.

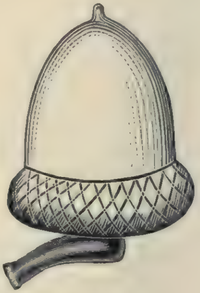


FIG. 317.

FIG. 314.—Caryopsis of the Oat.
FIG. 315.—Samara of the Ash.

FIG. 316.—Samara of the Elm.
FIG. 317.—Glans of the Oak.

(2) The *Utricle*. This is similar to an akene, but the pericarp is bladdery and fits the seed loosely; for example, the fruit of Chenopodium, Fig. 313.

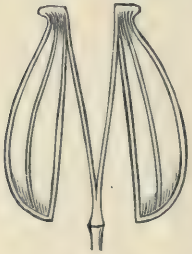


FIG. 318.

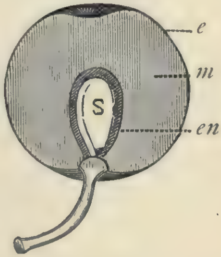


FIG. 319.

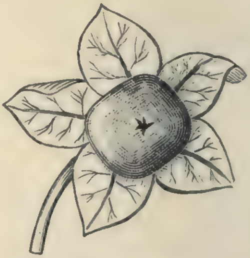


FIG. 320.

FIG. 318.—Cremocarp of Fennel, splitting into two mericarps.
FIG. 319.—Sectional view of drupe of Cherry; *e*, exocarp; *m*, mesocarp; *en*, endocarp, and *s*, seed.
FIG. 320.—Berry of Belladonna.

(3) The *Caryopsis*. This resembles the akene, except that the pericarp closely adheres to the seed, as in the Wheat, Indian Corn, Oat, etc., Fig. 314.

(4) The *Samara*. This resembles an akene, except that it possesses a wing-like appendage. Fig. 315 represents the samara

of the Ash, Fig. 316 that of the Elm, and Fig. 306 the double samara of the Maple.

(5) The *Glans*, or nut. This is a fruit, like that of the Oak or Hazel, with a thick, hard pericarp, enclosed, or partly so, in an involucre, Fig. 317. In the case of the Acorn, the involucre consists of a cup-shaped expansion of the axis covered by closely imbricated scales, and is called the *cupule*.

(6) The *Cremocarp*. This is the peculiar double fruit produced by umbelliferous plants. Each *mericarp*, or half of the fruit, structurally resembles an inferior akene, but is longitudinally ribbed, and there are usually oil tubes between the ribs. Fig. 318 represents the cremocarp of Fennel. By some botanists it is regarded as a variety of capsule.

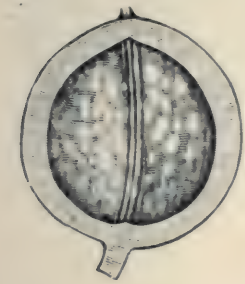


FIG. 321.

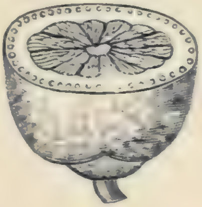


FIG. 322.

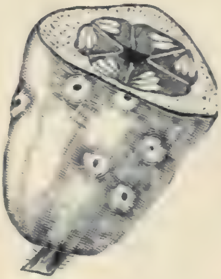


FIG. 323.

FIG. 321.—Tryma of Juglans regia, the English Walnut, with portion of sarcocarp removed.
FIG. 322.—Fruit of Lemon, cut transversely, illustrating a hesperidium fruit.
FIG. 323.—Cucumber, cut transversely, illustrating pepo fruit.

(7) The *Drupe*. This is a one-carpelled fruit like that of the Plum, Cherry and Peach, and is often called a stone fruit. In it the wall of the pericarp is differentiated into three portions, the outer or "skin," called the *exocarp*, the middle or succulent portion the *mesocarp*, and the inner portion or hard wall enveloping the seed, the *endocarp* or putamen. Fig. 319 represents the drupe of the Cherry in longitudinal section.

(8) The *Tryma*. This is a fruit structurally resembling the drupe, but the mesocarp is harder, more fibrous, the outer husk in most cases ultimately dehiscent, and the cavity containing the seed is usually more or less distinctly two-celled. The fruits of the Hickory, Walnut and Pecan are illustrations. See Fig. 321.

(9) The *Berry*. This is a fruit which has a thin, membranous rind, and all the rest of the pericarp is succulent. The fruits of the Belladonna, Grape and Gooseberry are illustrations. Berries may be one, two or even many celled, and they may be derived either from a pistil which is free from the calyx or from one which has an adherent calyx. In the former case the berry is called superior, in the latter inferior. Fig. 320 represents the berry of Belladonna.

(10) The *Hesperidium* is a fruit like the orange, Lemon and Lime. It resembles a superior berry, but differs from one in having a leathery rind containing numerous oil glands. See Fig. 322.

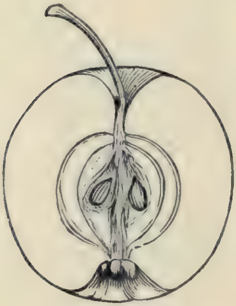


FIG. 324.

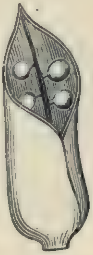


FIG. 325.

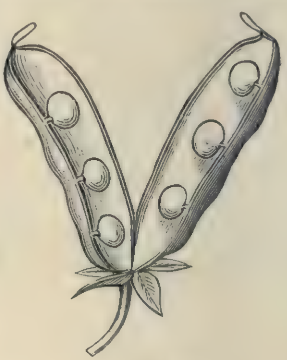


FIG. 326.

FIG. 324.—Sectional view of a pome, the fruit of the Apple.
FIG. 325.—Follicle of the Columbine.
FIG. 326.—Legume of the Pea.

(11) The *Pepo*. This is a fleshy fruit like that of the Gourd, Melon and Cucumber, having a hardened or tough rind, Fig. 323.

(12) The *Pome*. This is a fleshy fruit, the chief bulk of which consists of adherent, fleshy calyx, as the Quince, Pear and Apple, Fig. 324.

The more important dehiscent fruits which are the product of a single pistil are the following:

(1) The *Follicle*. This is a one-carpelled, dry fruit, that dehisces along the ventral suture, as the fruit of the Columbine, Fig. 325.

(2) The *Legume*. This differs from the follicle only in the fact that the dehiscence takes place along the dorsal as well as the ventral suture, forming two valves. This form of fruit is

common in the Pulse family. The Pea-pod, Fig. 326, is an illustration.

(3) The *Loment.* This is a modification of the legume, which, instead of dehiscing longitudinally breaks up transversely into segments, as the fruit of Sanfoin, Fig. 327.

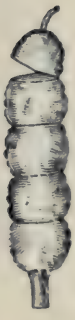


FIG. 327.

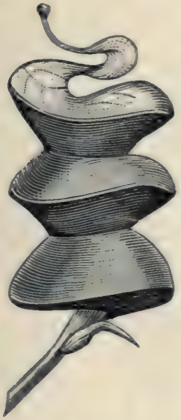


FIG. 328.

FIG. 327.—Loment of Sanfoin.
FIG. 328.—Cochlea of Medicago.

(4) The *Cochlea* is a coiled legume like that of the Medicago, Fig. 328.

(5) The *Capsule* differs from the dehiscent fruits above described in consisting of two or more united carpels. In this form of fruit, several modes of dehiscence are observed. The rupture of the pericarp may take place along the sutures of the carpels, as is more commonly the case, or independently of them; if the dehiscence is sutural, it may be along the marginal sutures only, along the dorsal sutures only, or along both; the splitting may be complete or only partial, and it may begin either at the apex or at the base. Sometimes the valves, in separating, carry the placentæ with them, at other times the latter are left behind, forming a central column, which is technically called the *columella*. The following are the commonest kinds of capsular dehiscence: (a) The *septicidal*, in which splitting takes place along the septa, or partitions, as in Fig. 329. (b) The *septifragal*, where the valves break away from the septa, as in Fig. 330. (c) The *loculicidal*, where the carpels open by their dorsal sutures

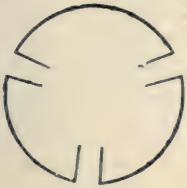


FIG. 329.

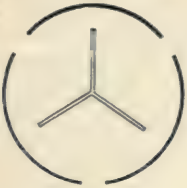


FIG. 330.

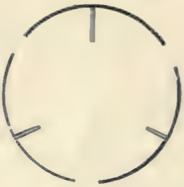


FIG. 331.

FIG. 329.—Diagram of the septicidal dehiscence of a capsule.
FIG. 330.—Diagram of the septifragal dehiscence of a capsule.
FIG. 331.—Diagram of loculicidal dehiscence of a capsule.

into the loculi or cavities of the cells, as in Fig. 331. All these are forms of valvular dehiscence. The Violet and Gentian afford examples in which the valvular dehiscence is complete, as shown in Fig. 332, while in the capsule of Lychnis, Fig. 333, it is partial or incomplete, and the partial separation takes place at the top of the capsules. In the capsules of the Hare-bell and of Cinchona Calisaya, see Fig. 334, it occurs at the base. (d) The *porous*. In this form, Fig. 335, the dehiscence takes place by small openings or pores, as in the Poppy. It is really a variety of the valvular dehiscence. (e) The *circumscissile* is

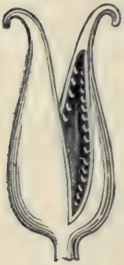


FIG. 332.

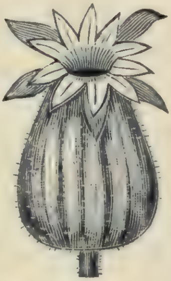


FIG. 333.

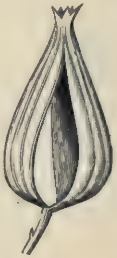


FIG. 334.

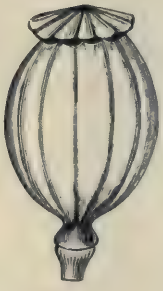


FIG. 335.

FIG. 332.—Capsule of the Gentian, dehiscing septicidally into two valves.
FIG. 333.—Capsule of Lychnis, showing partial dehiscence of capsule.
FIG. 334.—Basally dehiscent capsule of Cinchona Calisaya.
FIG. 335.—Capsule of the Poppy, showing porous dehiscence.

that form in which the upper portion of the capsule separates from the lower, like a lid, by a transverse dehiscence, as in the capsule of Hyoscyamus, Fig. 336. Such a capsule is often termed a *pyxis*. (f) The *irregular*, or that form in which the dehiscence takes place in an indefinite manner or by an irregular rupture of the pericarp, as in the garden Snap-dragon.

The following capsules have peculiarities which make it convenient to apply special names to them: One which is elongated, two-valved, and the valves of which separate from the base upward, leaving the seed-bearing placentas in place, as in the Mustard and Celandine, Fig. 337, is called a *silique;* and a shortened silique, like that of Shepherd's Purse, Fig. 338, is termed a *silicle*.

Fruits that are the product of one flower, but of more than one pistil, are often called *aggregated* fruits.

An aggregated fruit that consists of a collection of small drupes, like that of the Blackberry and Raspberry, is called an *etærio.* A *strawberry* is an aggregation of akenes on a thickened and succulent conical or convex receptacle. A *hip* is an aggregation of akenes on a thickened and succulent hollow receptacle. The term is applied to the fruit of the Rose.

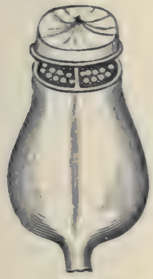


FIG. 336.

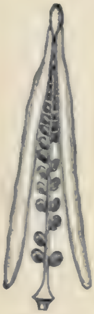


FIG. 337.

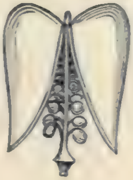


FIG. 338.

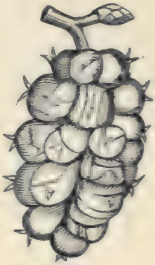


FIG. 339.

FIG. 336.—Pyxis of Hyoscyamus.
FIG. 337.—Silique of Celandine.
FIG. 338.—The dehiscing silicle of Shepherd's Purse.
FIG. 339.—Sorosis of the Mulberry.

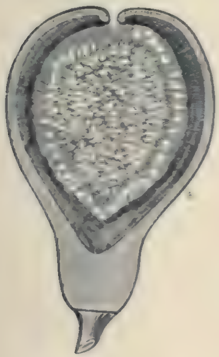


FIG. 340.

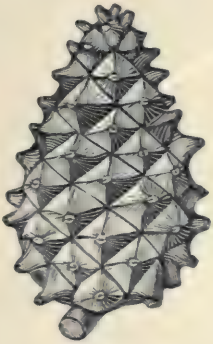


FIG. 341.

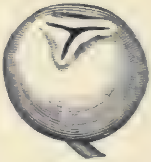


FIG. 342.

FIG. 340.—Syconium of the Fig-tree, shown in longitudinal section.
FIG. 341.—Strobile, or cone of Pine.
FIG. 342.—Galbulus of Juniper.

Fruits that are the products of flower-clusters instead of single flowers are termed *collective* or *multiple* fruits. The most important are the following :

(1) The *Sorosis.* This is a fruit like those of the Mulberry,

Fig. 339, and Pineapple, where the inflorescence in ripening has become fused together into a compact mass.

(2) The *Syconium*. This is the peculiar fruit of the Fig, the edible portion of which consists of a succulent, hollow receptacle, which incloses a multitude of akene-like nuts, each the product of a distinct flower, Fig. 340.

(4) The *Strobile*, or Cone. This is a multiple fruit consisting of a scale-bearing axis, each scale enclosing one or more seeds ; for example, the cones of the Hop and Pine, Fig. 341.

(4) The *Galbulus*. This is a cone, the scales of which have become succulent. The so-called Juniper Berry, Fig. 342, is an example.

RECAPITULATION OF FRUITS.

Fruits.	Product of a Single Flower.	One Pistil.	Indehiscent Fruits.	The akene, utricle, caryopsis, samara, glans, cremocarp, drupe, tryma, berry, hesperidium, pepo and pome.
			Dehiscent Fruits.	Follicle, legume, loment, cochlea, capsule, silique, silicle and pyxis.
		More than One Pistil.	Aggregated.	Etærio, strawberry and hip.
	Product of a Flower-Cluster.	Multiple or Collective Fruits.		Sorosis, syconium, strobile and galbulus.

II.—THE SEED.

The seed is the fertilized and ripened ovule. It ordinarily remains enclosed within the ovary, and is nourished by it until maturity, though the rule has some exceptions. As might have been expected, also, the seed ordinarily bears a general resemblance to the ovule from which it is derived. For example, the coats usually remain to form the coats of the seed ; the chalaza and micropyle of the ovule are still recognizable and are called by the same names in the seed ; the rhaphe, if present in the former, is also present in the latter ; the position of the seed in the ovary corresponds to that of the ovule ; the terms atropus, campylotropous, etc., apply equally well to the seed, and the latter, when ripe, breaks away from the funiculus, if that organ is present, or if not, from the placenta, leaving a scar called the hilum, which corresponds to the part called the hilum in the ovule. But notwithstanding the structural resemblance in many particulars, the ovule undergoes important changes, not only in size but also in form and structure, in the course of its development into the seed. Among the most important of these are the following :

(1) *The seed-coats*, particularly the outer, frequently undergo considerable modification. While the exterior one of the ovule is thin, membranous and smooth, that of the seed, termed the *testa* or *episperm*, is usually considerably thickened, and acquires various markings or appendages.

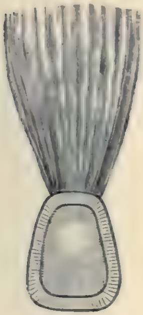


FIG. 343.

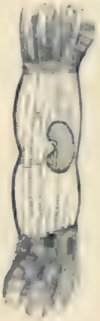


FIG. 344.

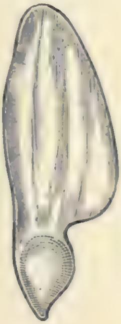


FIG. 345.

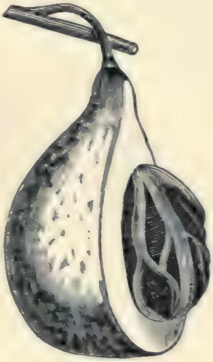


FIG. 346.

FIG. 343.—Comose seed of the Milk-weed.
FIG. 344.—Alate or winged seed of the Catalpa.
FIG. 345.—Alate seed of the Pine.
FIG. 346.—Fruit of Nutmeg, with one side removed, to show the seed enveloped in the mace.

If the testa becomes very thick, hard and resistant, it is termed *crustaceous ;* if smooth and shining, it is described as *polished ;* if roughened, it may be *tuberculate*, *pitted*, *rugose*, *reticulate*, *alveolate*, *fissured*, *furrowed*, *hairy*, etc.; and if appendaged, the appendages may be in the form of a *coma*, or long hairs, which either cover the entire seed, as in the Cotton, or only one end of it, as in the Milkweed, Fig. 343 ; or the appendage may be in the form of short silky hairs, as in the seeds of Nux vomica ; or of one or more flattened expansions, called *wings*, as in the seed of the Catalpa, Fig. 344, and of the Pine, Fig. 345 ; or it may be an outgrowth from the funiculus or placenta, which more or less completely envelops the seed, and constitutes the *aril*, as in the mace of the Nutmeg, Fig. 346, the aril of the Water-lily, and that of Celastrus scandens ; or, lastly, it may be in the form of a cellular excrescence at the hilum or along the raphe, called the *caruncle*, or crest, as in the seed of Sanguinaria, Fig. 347. Not infrequently, also, the outer portion of the testa undergoes change into mucilage, as in the seeds of the Quince and Flax.

The inner coat of the seed, called the *tegmen* or *endopleura*, is sometimes wanting, sometimes it coalesces with the outer coat and becomes indistinguishable from it, or it may unite with the nucleus. When present, it is usually thin and membranous.

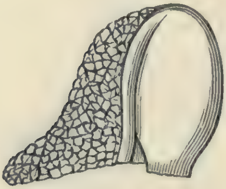


FIG. 347.

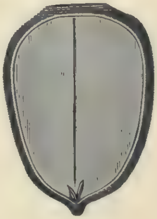


FIG. 348.

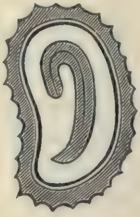


FIG. 349.

FIG. 347.—Carunculate seed of the Blood-root. Magnified.
FIG. 348.—Longitudinal section of acorn, showing the exalbuminous seed.
FIG. 349.—Albuminous seed of Hyoscyamus, shown in longitudinal section. Magnified.

(2) *The internal structure* of the nucleus undergoes important changes. Some of these were mentioned under the subject of fertilization.

The nucleus of the seed, or that portion within the seed-coats, may, as we have already seen, consist either entirely of the embryo, in which case it is described as *exalbuminous*, as in the Acorn, Fig. 348, or of the embryo, together with more or less nourishing matter called, according to its origin, either *endosperm* or *perisperm*, in which case the seed is termed *albuminous*, as in Fig. 349, which represents a section of the seed of Hyoscyamus. The term endosperm, as already explained, is applied to the nutritious matter developed outside the embryo but within the embryo-sac, while perisperm is applied to the nutritious matter stored up outside of the embryo-sac. Both serve the same purpose, and in the fully developed seed it is often difficult, if not impossible, to distinguish them.

In albuminous seeds the amount of albumen differs very widely, and in describing it, it is usual to compare its quantity with that of the embryo. If much greater it is *copious*, or abundant; if about the same, *equal;* and if comparatively small in quantity, *scanty*.

The texture of the albumen differs, also, in different seeds. In some, like the Wheat and Buckwheat, it is *farinaceous*, or mealy; in the seeds of Barberry and Cocoanut, it is of a denser consistency, yet readily cut with a knife, and is called *fleshy;* in some, as the seeds of Poppy and Bloodroot, it is *oily;* in the seeds of Nux vomica and many others it is *horny;* in others still, as that of the Ivory Palm, it is so exceedingly hard as to be appropriately called *bony;* and in the seed of the Nutmeg, since it has an uneven or marbled appearance, and is more or less fissured transversely, it is called *ruminated*.

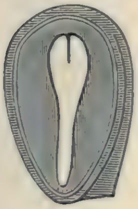


FIG. 350.

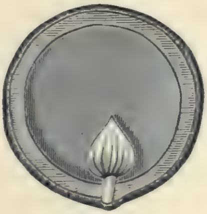


FIG. 351.

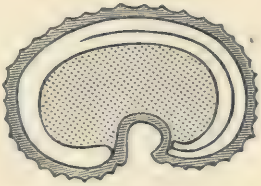


FIG. 352.

FIG. 350.—Seed of Violet, showing straight embryo buried in the albumen. Magnified.

FIG. 351.—Seed of Nux vomica, with one side removed, showing position of embryo. About natural size.

FIG. 352.—Seed of Lychnis dioica, showing embryo curved around the albumen. Magnified.

The Embryo. This is the essential part of the seed; it is the young plant which is the end and purpose of the entire flower and fruit; it is the finished product of the reproductive process.

In *exalbuminous* seeds it is usually well developed, while in *albuminous* ones it is apt to be smaller, and have its parts less perfectly formed, but this general rule has many exceptions.

As respects the position of the embryo in the seed, it has already been noted that the radicle always points to the micropyle. As regards its position with reference to the albumen, this varies greatly in different seeds. In the seed of the Violet, Fig. 350, it is straight, and buried in the albumen. This is true, also, of the relatively smaller embryo of Nux vomica, Fig. 351; in the seed of Hyoscyamus, already mentioned, it is curved within the albumen; in the seed of Lychnis dioica, Fig. 352, it is curved, but lies on the outside of it, and almost completely surrounds it, while in the Indian Corn, Fig. 353, it is placed to one side of it.

An embryo that is well developed, like that of the Bean, Figs. 354 and 355, possesses four parts, a stemlet, or *caulicle;* at the lower end of this the beginning of the root, called the *radicle;* near the upper end of the caulicle two thickened bodies more or less resembling leaves and homologous with them, the *cotyledons;* and between these a small bud called the *plumule.* Thus, in the embryo, all the organs of vegetation are already present except plant hairs.

The cotyledons, although in their nature leaves, and sometimes doing for a time the work of foliage, as those of the Maple and Morning-glory, are commonly thickened and surcharged with nourishment which serves to feed the growing plantlet; in many instances this function is the only one they discharge. This is the case with the embryos of the Pea and Oak. In these instances they do not rise above the soil at all in germination, but remain buried in the ground until their supply of nutriment has been exhausted by the growing

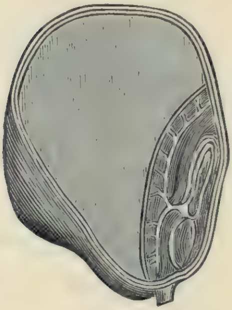


FIG. 353.

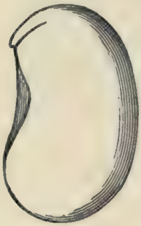


FIG. 354.

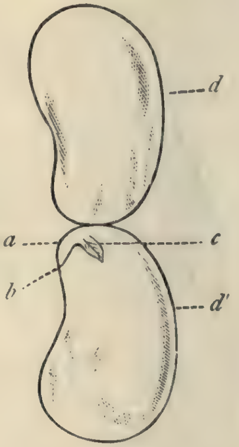


FIG. 355.

FIG. 353.—Seed of Indian Corn, showing embryo placed to one side of the albumen. (After Sachs).

FIG. 354.—Embryo of Bean.

FIG. 355.—The same, with one of the cotyledons turned back to show the plumule. *a*, the caulicle; *b*, the radicle; *c*, the plumule; *d* and *d'*, the cotyledons.

plantlet, when they decay and disappear. Such cotyledons are described as *hypogeal*, while those which rise above the soil are called *epigeal*.

Embryos like those of the Bean, because they possess two opposite cotyledons, are called *dicotyledonous*. Not all embryos, however, are constructed on precisely this plan. Some, as those of Lilies, Sedges and Grasses, have the leaves alternate from the start, and usually the lower one is much the most highly developed, and being the only conspicuous one, besides being folded about the rest and concealing them from view, the embryo is called *monocotyledonous*. Fig. 356 represents the monocotyledonous embryo of Indian Corn. The embryos of some other plants, particularly of many members of the Pine family, have more than two cotyledons in a whorl—sometimes as many as fifteen; embryos of this kind are sometimes described as *polycotyledonous*. Fig. 357 represents the germinating embryo of a species of Pine. There are a few cases in which the cotyledons are aborted or wanting. Such embryos have been called *acotyledonous*. The seed of the common Dodder contains an embyro of this kind. There is much reason to believe, however, that it was once *dicotyledonous*, for the affinities of that plant, as shown by the structure of its flowers, are with Dicotyledons. The plant is, however, a parasite, and, doubtless, the loss of its cotyledons bears some relation to its parasitic habits. Probably once, like its near relative, the Morning-glory, it possessed foliage, and obtained its living in a legitimate way, but having acquired the parasitic habit (a habit degrading alike to plants, animals and men), and having no use for foliage of its own, it lost its leaves, and the degradation of form came finally, even to affect the embryo and cause the loss of its cotyledons. These probably were once highly developed and did partial duty as foliage, as those of the Morning-glory still do.

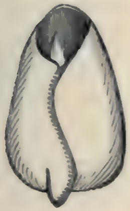


FIG. 356.

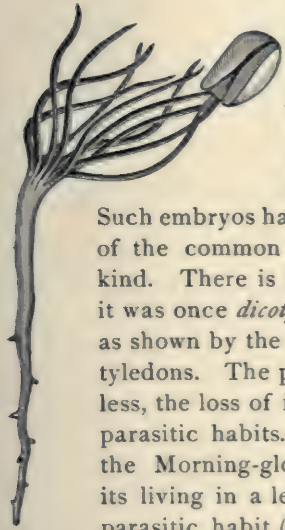


FIG. 357.

FIG. 356.—Monocotyledonous embryo of the Indian Corn.

FIG. 357.—Polycotyledonous embryo of a species of Pine, Pinus Pinea. (After Sachs).

There are a few instances, also, where plants whose actual affinities are with Dicotyledons, possess but one cotyledon, the other having become aborted, the embryos thus becoming falsely monocotyledonous. This is the case with Abronia. Plants of this kind should not be confounded with true Monocotyledons.

The distinction between monocotyledonous and dicotyledonous embryos is, with these exceptions, one of fundamental importance,—one of the great divisions of the flowering plants, the Monocotyledons, being characterized by monocotyledonous embryos, and another, the Dicotyledons, by dicotyledonous ones.

The individual cotyledons may be folded or bent in various ways in the seed, as leaves are in the bud, and their folding may be described in the same way. They also have a variety of shapes, the same as ordinary leaves, though they are much more commonly entire. Occasionally, however, we find them toothed or lobed, as in the embryo of the Basswood, Fig. 358.

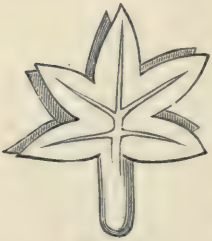


FIG. 358.

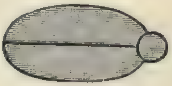


FIG. 359.

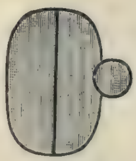


FIG. 360.

FIG. 358.—Embryo of Basswood, showing lobed cotyledons. Magnified.
FIG. 359.—Diagram illustrating accumbent cotyledons.
FIG. 360.—Diagram illustrating incumbent cotyledons.

Although we often find the embryo straight, or the caulicle lying in the same line as the cotyledons, in many seeds it is bent so as to lie alongside of them. In this case it may be applied to their edges, as shown in the diagram, Fig. 359, which represents a cross-section through the cotyledons and caulicle, in which case it is described as *accumbent;* or it may be applied to the outer face of one of them, as in Fig. 360, when it is described as *incumbent.* An illustration of the former arrangement occurs in the seed of the garden Candy-tuft, and of the latter in the seeds of Shepherd's Purse.

The number of seeds produced by some plants is enormously great. A single Poppy capsule, according to Cooke, has been known to contain as many as forty thousand seeds, and the

Poppy is certainly much less prolific than many other flowering plants. If all the seeds of almost any ordinary tree were to germinate and reach maturity, and the seeds of all these in turn were to develop, but a few generations would suffice before the earth would be so crowded with them that no room would be left for other plants. But, as a matter of fact, only a few of the large number of seeds produced by a plant ever reach maturity. The young plantlet has to contend with a thousand enemies, in the form of destructive insects, beasts and fellow plants; it must often wage war, also, against unfavorable conditions of soil and climate, against heat and cold, wet and drouth, and be hampered by the shadows cast by its older and stronger brethren. It is fortunate if, in the bitter struggle for existence, it survives to help gladden the earth with bloom and verdure, for the great majority perish.

PRACTICAL EXERCISES.

1. Study the following fruits, and classify and name them according to the system given you in this chapter: The Watermelon, the Banana, the Raspberry, a grain of Corn, the Butternut, the Almond, the Osage Orange, the Plum, the Sunflower fruit, the fruit of the Locust, that of Stramonium, of Red Cedar, of the Carrot and of the Beet.

2. Study the following fruits with reference to the adaptations for dispersion, and write out your conclusions regarding each: The fruit of Dog-bane, of the wild Plum, of Agrimonia, of the wild Geranium, of the Elm, of Cleavers, of the Clot-bur, of the garden Balsam, of the wild Cucumber (Echniocystis), of the Grape and of the Hound's-Tongue.

3. Examine seeds of the following plants with reference to the surface markings, the coats, the position of the hilum, the micropyle and the rhaphe: The Bean, the Pea, the Pumpkin, the Almond, the Stramonium and the Nux vomica.

4. Soak the following seeds for twenty-four hours in tepid water; then remove the seed-coats and study the albumen and embryo: The Bean, the Maple seed, the seed of Hemp, the seed of Morning-glory, the seed of the White Pine, the seed of Indian Corn, and that of the Horse-chestnut. Determine (1) which of these seeds are albuminous and which are exalbuminous; (2) the position of the embryo as regards the albumen in case the seed possesses the latter; (3) the parts of the embryo present in each case; (4) draw a diagram of each, representing the shape and parts of the embryos, and determine whether, in any instance, the caulicle is accumbent.

PART II.

VEGETABLE HISTOLOGY.

CHAPTER I.

INTRODUCTION.—THE CELL IN GENERAL.—THE CELL-WALL.—THE PROTOPLASM AND OTHER CELL-CONTENTS.

Vegetable Histology has already been defined as that branch of botany which treats of the microscopic structure of plants. To pursue it successfully the student should be provided with a good compound microscope, having a range of magnifying powers of from twenty-five to about seven hundred diameters, and he should make use of it to verify, by actual observation, the descriptions given in the text. To aid him in this, and especially to assist the student who wishes to pursue the subject without the aid of a teacher, "Practical Exercises" have been prepared and appended to each chapter; and there is given, in the Appendix to this Part, a description of the more important apparatus, micro-reagents, staining fluids, etc., used in vegetable histology.

The Cell in General. A cell has been defined as *a nucleated mass of protoplasm.* It may or may not possess a cell-wall of different composition. In the majority of vegetable cells such a wall is present, while most animal cells are destitute of it; but in all essential respects animal and vegetable cells resemble each other. Cells constitute the structural units of the organism. All plant bodies are composed of cells or of these together with the products of cell activity. Within the compass of the cell occur all those essential phenomena which are called *vital;* the life of the plant resides in its cells; the sum of the activities it exhibits is the sum of the activities of its component cells.

Vegetable cells, on the average, are not more than the one five-hundredth or the one six-hundredth of an inch in diameter, though in some cases they are large enough to be distinctly seen by the unaided eye, as in the flesh of the Water-melon and the pith of the Elder; in rare instances, as in the inter-nodal cells of Chara and Nitella, they may even be upwards of an inch in length. Some, on the other hand, are so small as to be barely visible under the highest powers of the microscope. This is the case with the cells of some Bacteria, and there is good reason to believe that there are some low organisms belonging to this type which no microscope yet made is powerful enough to resolve.

The primary form of cells appears to be that of a sphere, or a spheroid, but commonly, especially as we find them in the tissues of the higher plants, they acquire forms quite different from this, and, even within the limits of the same organism, the shapes may be exceedingly various. This may be due to mutual pressure, to unequal growth caused by the unequal operation of various physical forces, as gravitation, light, etc., or to other influences. Cells, like the organs of which they are components, undergo many modifications of form and structure, adapting them to different uses. The cells which make up the body of a living tree are comparable to the human units which make up society. As in the latter case, the various individuals resemble each other fundamentally,—that is, as to origin, general endowments, and essential structure,—so do they also in the former. As in the social body men differ in rank, in occupation, in mode of life, and in habits of thought, thus producing different classes, each contributing to the structural whole, so also cells are divided into classes, each class having a somewhat different function, but each contributing to the life of the whole organism; and as in society individuals come and go, while the community as a whole lives on, so in the tree cells come into existence, live their short lives, perish, and are succeeded by others, while the life of the organism, as a whole, continues. A plant, then, at least one of the higher plants, is a community or republic of cells. To understand it, one must understand the individuals that compose it. Let us first, therefore, study the cell in its typical form, and then afterward in its various modifications.

The typical vegetable cell is a spherical or spheroidal body like that represented in Fig. 361. It has an outer membranous wall of cellulose, a substance composed of carbon, hydrogen and oxygen in the proportion represented by the formula $C_6 H_{10} O_5$, though in all probability the true formula of its molecule is more complex than this, containing two, three or more times this number of atoms of each element.

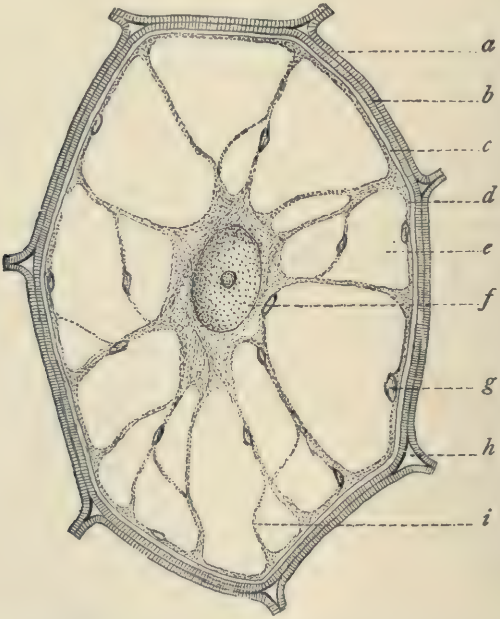


FIG. 361.—Represents a parenchyma cell, greatly magnified, to show the parts. *a*, the cell-wall; *b*, the middle lamella; *c*, the ectoplasm; *d*, endoplasm; *e*, vacuole; *f*, nucleus; *g*, chlorophyll corpuscle; *h*, intercellular space; *i*, protoplasmic thread.

In mature cells aggregated to form tissues, the common cell-wall between adjacent cells consists of two similar portions separated from each other by a substance of slightly different chemical composition, and more soluble in re-agents than the rest of the wall, called the middle lamella, Fig. 361, *b*, and at the angles where the cells join are usually found small, angular intercellular spaces, Fig. 361, *h*. Interior to the cell-wall is the living matter of the cell, the protoplasm, together with cell-sap, and products of various kinds, which are the results of the activity of the cell.

The protoplasm is a nearly transparent, semi-fluid substance, of very complex character. Its chemical formula has not been determined, but it is known to contain carbon, hydrogen, oxygen, nitrogen, sulphur, and some forms of it, at least, phosphorus. It is probably a combination of several different albuminous substances, with admixtures in larger or smaller proportions of water, carbo-hydrates, oils, and mineral matters. The outer layer of the protoplasm is in intimate contact with the cell-wall, and, being somewhat tougher and firmer than the rest, constitutes a kind of inner cell-wall called the *primordial utricle.* This is imperfectly differentiated into two layers, an outer one, called the *ectoplasm*, which is perfectly transparent and free from granules, Fig. 361, *c*, and an inner one, called the *endoplasm*, which contains minute granules, and often, also, chlorophyll corpuscles. Fig. 361, *d.* Located somewhere in the interior of the cell, or else in contact with the endoplasm, is a rounded, granular and more highly refractive body called the *nucleus*, Fig. 361, *f.* and in the interior of the latter, one or more opaque bodies called the *nucleoli.* In a fully formed and active cell, like that represented in the figure, there are threads or bands of protoplasm, connecting the nucleus with the primordial utricle, and in these bands chlorophyll-corpuscles or other proteid masses commonly occur, Fig. 361, *i.* The spaces between them contain cell-sap, and are called vacuoles. Fig. 361, *e.* The position of the nucleus and the connecting bands and threads of protoplasm is not constant, but continually undergoes change. The movements are ordinarily slow, but they are sometimes sufficiently rapid to be directly observable by means of the microscope. Currents are also observed about the nucleus, in the endoplasm, and in the threads and bands, showing that the living matter of the cell is in a state of constant activity.

In the very young cell the wall is exceedingly thin, and apparently homogeneous, the vacuoles are absent, and the entire area inclosed by the wall appears to be filled with protoplasm, Fig. 362 ; but as the cell grows older, its walls become thicker and differentiated as described above ; they often become excessively thickened, and not infrequently undergo important chemical changes ; by the expansion of the cell-wall, also, the cavity of the cell increases faster than the contained protoplasm ;

the latter imbibes more water than it is capable of holding in solution, and so sap cavities or *vacuoles* are formed in it, which, at the maturity of the cell, often occupy more space than the protoplasm itself, and, finally, when the cell grows old, its living contents disappear, and the cell becomes dead matter.

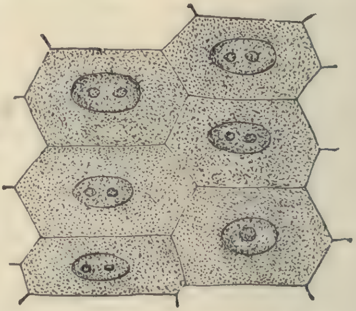


FIG. 362—Young cells from near the apex of a growing root. Magnified about 300 diameters.

The term *cell*, as applied to the structural unit of plant life, is not strictly appropriate, since it contains the idea of an inclosure. When first used in this sense it was because of a mistaken notion regarding its true character; it was supposed to be a closed cavity, and the subordinate nature of the cell-wall was not understood; but we now know that the protoplasm, and not the cell-wall which incloses it, is the essential part, and that an uninclosed, nucleated mass of protoplasm, that is in no sense a closed cavity, is capable of performing all the essential functions of a cell, and must be regarded as such. It is, however, better to retain the old word and give to it an extended meaning than to discard a term which long usage has rendered familiar.

Cells which are destitute of a cell-wall are called *primordial* or naked cells. Though common in the animal kingdom, they are comparatively rare in the vegetable world, occurring mostly among the low forms of plant life.

Let us now consider more particularly the different parts of the cell.

The Cell-Wall. The cellulose of the cell-wall is not in the proper sense living matter, although when young it is permeated by protoplasm which is living matter. As the cell grows older, the protoplasm contained in its wall diminishes in quantity, and finally disappears, while the cellulose increases in quantity. These, among other facts, lead to the conclusion that it is produced by the transformation of the protoplasm. At its first formation the cell-wall is a delicate film of even thickness, but as growth proceeds, it not only becomes thickened to a greater or less extent, but usually unequally so, and this gives rise to markings more or less conspicuous, which may either be irregular in form and distribution, or else quite regular and characteristic of certain classes of cells. The markings may take the form of thickenings or protuberances on the outside of the cell-wall, as in the pollen grains of the Mallows, Fig. 248. This cannot well occur, however, except in cells which become independent at or before maturity. In those which are united to form tissues they are seen as thickenings on the inner surface of the wall. These may form rings, spirals or reticulations, or they may be so arranged that the unthickened portions form circular or oblong disc-like markings. These, in old cells, frequently become perforations. The markings of cells will be more fully described when we come to treat of the different kinds of tissues.

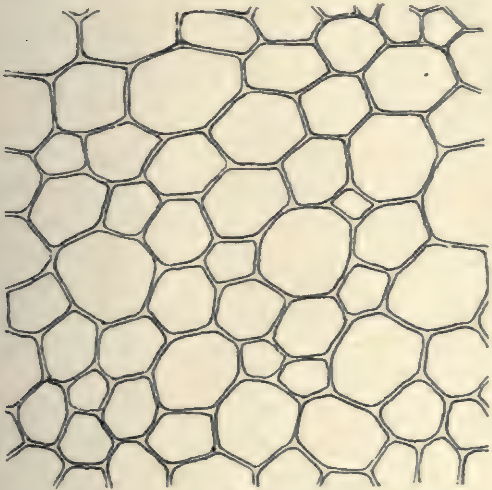


FIG. 363.

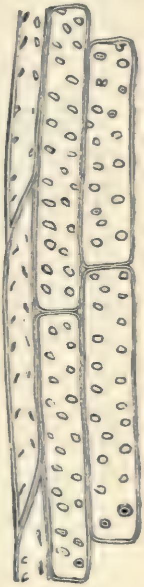


FIG. 364.

FIG. 363.—Polygonal parenchyma cells from the pith of Clematis Virginiana, showing the effects of mutual pressure. Magnified 125 diameters.

FIG. 364.—Elongated cells from the stem of the common House Geranium. Magnified about 250 diameters.

The cell-wall, besides increasing in thickness, grows also in surface area until it reaches maturity. Sometimes the growth is nearly equal in all directions, giving rise to spherical or spheroidal forms, or if the cells are aggregated into masses, the tendency to an equiaxial growth may be modified by mutual pressure, producing cuboidal or polyhedral forms, Fig. 363; sometimes the growth is greater in one direction than in any other, and elongated cells like those in Fig. 364 are the result; or, lastly, by a more exuberant growth in two or more different directions, tabular, star-shaped, or variously branching forms may be produced. Cork and epidermal tissues often afford examples of tabular cells. Fig. 365 represents a group of stellate cells from the stem of the Pickerel-weed, Pontederia cordata, and Fig. 366, a peculiar branching cell from the stem of the Yellow Water-lily, Nuphar advena.

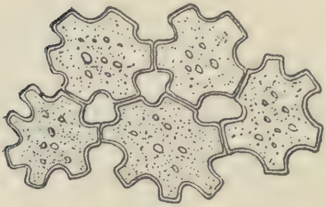


FIG. 365.

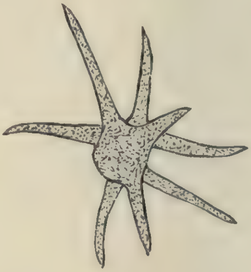


FIG. 366.

FIG. 365.—Stellate cells from the stem of the Pickerel Weed, Pontederia cordata. Magnified about 180 diameters.

FIG. 366.—Branching cell (trichoblast) from the stem of the Yellow Water-lily, Nuphar advena. Magnified about 75 diameters.

When the cell-wall is first formed, it nearly always consists essentially of cellulose, but it may subsequently undergo modifications, or become changed in appearance and chemical behavior by the infiltration of other substances. These changes may be of various kinds:

1. The formation of a middle lamella, which has already been described.

2. The formation of *cutin*, or cork-substance. The outer portion of the cell-walls of epidermal cells often undergoes this kind of change, while the rest remains unmodified. As this substance is nearly impermeable to wear, it forms, when present, a protecting covering to the plant. In the case of cork cells, the entire cell-wall becomes encrusted by it, and in some instances, at least, the primary cellulose wall is even changed into it. Cork-substance is often called *suberin*, but no essential difference exists between it and cutin.

3. The formation of *lignin*, or wood-substance. This constitutes the great bulk of the wood of trees, and differs in chemical properties both from cutin and cellulose. The middle lamella, already described, is a form of lignin.

4. The infiltration of coloring matter. This not infrequently occurs in old and lignified cell-walls, such as those of the heartwood of trees. The colors thus produced are often quite characteristic, as, for example, those of the wood of Cherry, Mahogany, Walnut, and Red Saunders.

5. The infiltration of mineral matters. The commonest of these are silica and calcium salts. Beautiful examples of the former occur in the cell-walls of Diatoms, where the silicification is very complete, and the silicified walls are often very delicately sculptured. Notable amounts of silica also exist in the walls of many plant-hairs, and in the ordinary epidermal cells of the Equisetums and many of the Grasses.

Calcium carbonate also frequently occurs in the cell-walls of hairs, in those of some seaweeds, as the Corallina, Acetabularia, etc., and in the curious cell-wall modifications called *cystoliths* found in the leaves of plants belonging to the Nettle and Acanthus families. See Fig. 389. Calcium oxalate occurs occasionally as a crystalline deposit in the walls of thick-walled cells, as in those of Welwitschia, see Fig. 367, but more commonly crystals of this kind are found among the cell-contents.

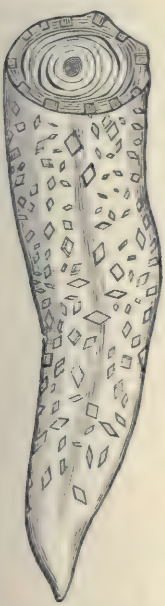


FIG. 367.—Half of a thick-walled cell from Welwitschia mirabilis, showing crystals of oxalate of calcium imbedded in the cell-wall. After Sachs.

6. The conversion into mucilage, or gum. Examples of this kind of change occur in the outer cells of the seeds of the Quince, Flax, many Polemoniums, etc. If any of these seeds be placed in water, the walls of the outer cells may be observed to swell, become transparent, and finally dissolve, forming a thick mucilage. The cell-walls of the pith and medullary rays of some plants become changed into gum. This is the case with the Astragalus plants that yield gum tragacanth.

It should also be noted that in the germination of some seeds, as that commonly called Vegetable Ivory, the cell-walls, as well as the cell-contents of the endosperm, are converted into soluble matter, which serves as food for the growing plantlet.

Thickened cell-walls are seldom homogeneous in structure, but if viewed in cross-section, they have the appearance of being arranged in concentric layers, as in Fig. 368. This is called *stratification*, and the phenomenon is due to the alternation of more watery layers with less watery ones. Thick-walled cells, like bast fibers, also frequently show on the outside delicate lines running transversely, obliquely or longitudinally, as shown in Figs. 369, 370 and 371. The term *striation* has been applied to this form of marking. In many cases, also, delicate, simple or branching tubes, called pore-canals, will be seen running from the cavity or lumen of the cell through the wall, Figs. 368 and 371. They doubtless facilitate the circulation of the sap from cell to cell.

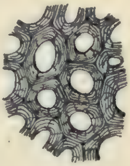


FIG. 368.

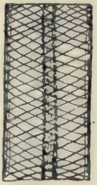


FIG. 369.

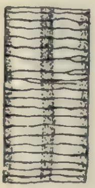


FIG. 370.

FIG. 368.—Transverse section of bast fibers from the stem of Aristolochia Sipho, showing stratification. Magnified about 300 diameters.

FIG. 369.—Portion of a bast fiber, showing oblique striation. Highly magnified.

FIG. 370.—Portion of bast fiber, showing transverse striation.

FIG. 371.—Bast fiber from the bark of Cinchona Calisaya, showing longitudinal striæ and small tubes connecting the lumen of the cell with the exterior. Magnified about 75 diameters.

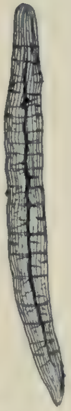


FIG. 371.

The Protoplasm. Protoplasm exists both in an active and in an inactive condition. In its active state, as found in rapidly growing cells, it exhibits motility and other vital phenomena in a marked degree; it imbibes large quantities of water, and becomes in consequence, nearly fluid, but as we find it in the cells of seeds, tubers, and thickened roots, it exhibits few signs of vitality, contains comparatively little water, and its condition approximates that of a solid.

The words *protoplasm* and *proteid* are not synonymous. The former is used in the physiological sense to indicate the living matter of the plant; the latter is rather a chemical term applied alike to the albuminous matter which makes up the bulk of living protoplasm and to matters of similar chemical nature which do not exhibit vital phenomena.

Ordinary protoplasm is formless; even when viewed under the highest powers of the microscope, it exhibits no evident structure beyond that already described, except the presence of great numbers of very minute granular bodies called *microsomes*, the nature and uses of which are not yet understood. It passes, however, into several modifications which exhibit a more or less characteristic structure. Among the most important of these are *chlorophyll bodies*. These are the proteid corpuscles that contain the green matter, chlorophyll, to which leaves and other green parts of plants owe their color. They are commonly rounded, oblong, or somewhat flattened, but sometimes take the form of spiral bands, as in the cells of Spirogyra, or of stellate masses, as in the cells of Zygnema, Figs. 372 and 373. Occasionally, also, they are found in other shapes. In a few instances, as in some green Protophytes, there are no chlorophyll bodies, but the green coloring matter is diffused through the unmodified protoplasm.

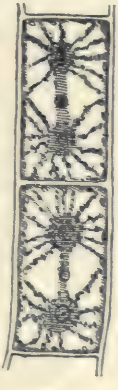


FIG. 372.

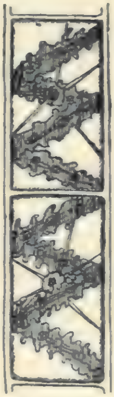


FIG. 373.

FIG. 372.—Two cells from Zygnema, a filamentous fresh water alga, showing stellate arrangement of chlorophyll. Magnified about four hundred diameters.

FIG. 373- Two cells from Spirogyra, a filamentous fresh water alga, showing spiral chlorophyll bands. Magnified about five hundred diameters.

Chlorophyll bodies are observed to contain in daylight minute starch grains, which at night dissolve and disappear. If a green plant be kept in darkness, no starch is found, and gradually the green color fades out of the chlorophyll bodies, and they become colorless or yellowish, and the plant consequently appears as if bleached.

In some plants, for example, the Red Marine Algæ and the Diatoms, other coloring matters dissolved in the cell-sap obscure or greatly modify the proper color of the chlorophyll.

The colors of many flowers and fruits are due to other proteid bodies of a similar character, which, however, contain a different coloring matter. These are called *chromoplasts*. See Fig. 374.

In those parts of plants which are removed from the light, and serve for the storage of reserve food materials, as seeds, tubers, etc., analogous bodies called *amyloplasts* are found. These are transparent, or faintly yellowish corpuscles, whose function appears to be to form starch-grains. In some plants the starch-grains are formed in their interior the same as in chlorophyll bodies, in others, on their surface. In Phajus grandifolius, an Orchid, they may be seen attached to one end of the forming granule. See Fig. 375.

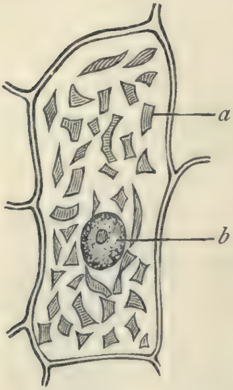


FIG. 374.—From upper side of calyx of Tropæolum majus. The inner wall of an epidermal cell with the angular color-bodies, *a*, adjacent to it; *b*, nucleus. Magnified about 540 diameters. After Strasburger.

Aleurone grains constitute another modification of protoplasm. This is one of the forms in which reserve proteid matter is stored up in the seed. They are more abundant and of larger size in oily than in starchy seeds. In shape they are usually more or less rounded; most of them contain a small, roundish or amorphous mass of mineral matter, composed of the double phosphate of calcium and magnesium, called a *globoid;* occasionally they contain crystals of calcium oxalate, and not infrequently the larger ones contain crystalloids, Fig. 376.

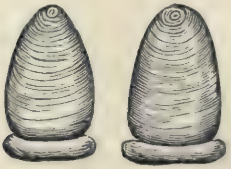


FIG. 375.

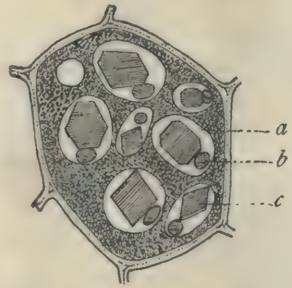


FIG. 376.

FIG. 375.—Two starch grains from Phajus grandifolius, showing nucleus at the upper end, and the amyloplast attached to the lower. Magnified about 1,000 diameters. After Schimper.

FIG. 376.—Cell from the Castor Bean (Ricinus communis), showing aleurone grains, etc., *a*, aleurone grain, containing globoid and crystalloid; *b*, globoid; *c*, crystalloid. Magnified about 1,000 diameters. After Sachs.

Crystalloids constitute another of the resting forms of protoplasm. They have the shape and appearance of crystals of mineral matter, but differ from them in the fact that they swell up and lose their angles when treated with a solution of potassium hydrate. They are stained yellowish brown by iodine and exhibit the other reactions of proteid matter. Although often enclosed in aleurone grains, they also occur independently in tubers and thickened roots, as well as in seeds.

Carbohydrates. These are complex substances containing carbon, to which are united hydrogen and oxygen in the same proportion as that in which they occur in the water molecule. Among the most important of this class of cell contents is *starch.* Its chemical composition is either $C_6H_{10}O_5$, or some multiple of this. It is, therefore, either isomeric or polymeric with cellulose. Its first formation, as has been stated, is due to the action of chlorophyll under the influence of sunlight, and it is temporarily deposited in the form of minute granules in the chlorophyll-bodies; but it subsequently undergoes solution, and that which is not immediately required in the formation of tissues is stored in various parts of the plant as a reserve food material. Thickened roots, tubers and seeds commonly contain it in abundance, but it also frequently occurs in the pith, medullary rays, and various other parts of the plant. It is seen in the form of hard granules of various sizes which often possess shapes and markings so characteristic that they may serve for the identification of the plant. In some cases the granules are simple; in others they are compound or aggregated into masses. The starches of the Potato, Wheat, Maranta and Curcuma afford examples of the former, while those of Oats furnish illustrations of the latter, Figs. 377, 378, 379, 380, 381.

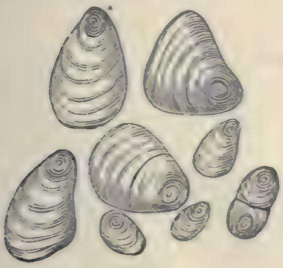


FIG. 377.

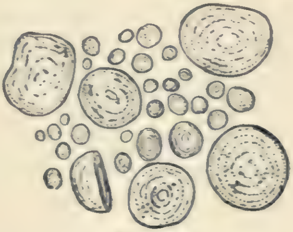


FIG. 378.

FIG. 377.—Starch grains from the potato tuber. Magnified about 200 diameters.
FIG. 378.—Wheat starch. Magnified about 500 diameters.

Well developed starch grains are observed to possess a nucleus or hilum, around which the rest of the granule is arranged in layers. These layers differ from each other somewhat in transparency, owing to the fact that some of them contain more water than others. This structure gives rise to the appearance of delicate markings, which, in case the nucleus is centrally located, as in the starch of the Bean, Fig. 382, are concentric, but if near one end, as in Potato and Curcuma starch, are eccentric. Starch grains are composed of two somewhat different substances, *granulose*, which forms the larger proportion of the weight of the grain, and *starch-cellulose.*

Inulin is a body which, chemically, is closely related to starch and isomeric with it. It takes the place of that substance in many members of the natural order Compositæ. It is abundant, for example, in the roots of Elacampane, Dandelion, Chicory, Dahlia, and the Artichoke. It is also occasionally found in members of other natural orders. It occurs in solution in the cell-sap, but if parts containing it be soaked for a time in strong alcohol, and sections of them be examined microscopically, sphere-crystals of it will be observed in the cells, as shown in Fig. 383. Iodine does not stain it blue, as it does starch, but, like starch, it is converted into glucose by the action of dilute sulphuric acid.

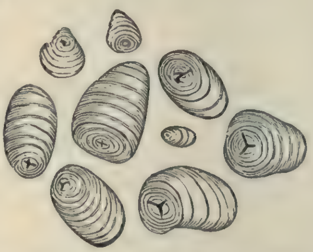


FIG. 379.—Maranta starch. Magnified about 275 diameters.

Among the other carbohydrates found in solution in the cell sap are *dextrin* ($C_6H_{12}O_6$), somewhat intermediate in its character between starch and sugar ; *mucilage* and *gum*, both closely related to starch, and in some cases, at least, derived from it, and the *sugars*, including glucose ($C_6H_{12}O_6$), cane sugar ($C_{12}H_{22}O_{11}$), and various other sugars.

Vegetable Acids. Among the more important of these may be mentioned malic acid ($C_4H_6O_5$), a very common acid in fruits, but also found in other parts of plants ; oxalic acid ($H_2C_2O_4$), an abundant and widely distributed vegetable acid ; citric acid ($C_6H_8O_7$), that which communicates the acidulous taste to lemons, limes, and other fruits of the Orange family of plants, and which not infrequently occurs, also, in other fruits, and tartaric acid ($H_6 C_4 O_6$), which exists in considerable quantity in grapes, but is not wanting in many other fruits. Many other acids, however, occur less abundantly. Among them may be mentioned acetic, formic, benzoic, cinnamic, gallic, butyric, valerianic, angelic, succinic, succinamic, and the fatty acids. Chemically, they differ much among themselves, some being highly complex, others comparatively simple; some are quite stable, while others are readily decomposable. They also differ much in their relations to the vital processes in the plant, some performing important functions, while others must be regarded as purely waste products. They may exist free or in combination with various bases. The acid reaction which many plants exhibit may be due either to the presence of free acids, or to acid salts in solution.

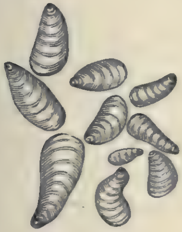


FIG. 380.

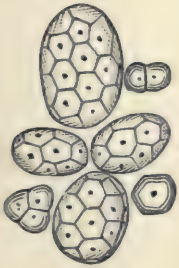


FIG. 381.

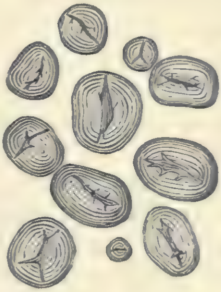


FIG. 382.

FIG. 380.—Curcuma starch. Magnified about 200 diameters.
FIG. 381.—Oat starch. Magnified about 375 diameters.
FIG. 382.—Bean starch. Magnified about 375 diameters.

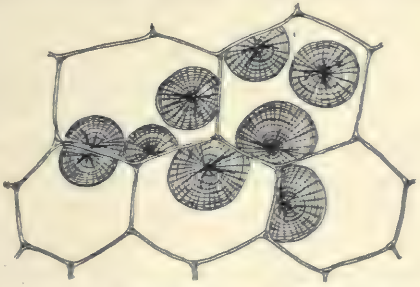


FIG. 383.—Cells from root of Dahlia that have been treated with absolute alcohol to precipitate the inulin. This is seen in the cells in the form of sphere-crystals. Magnified about 250 diameters.

Fixed Oils or Fats. These occur in the cells of various parts of plants, but are particularly abundant in certain fruits, as that of the olive, and in many seeds. In the latter instance, they replace starch as a reserve food material, and hence are of great importance to the life of the plant. Chemically considered, they are combinations of glycerine with various fatty acids, as oleic, stearic, palmitic and myristic acids.

The *waxes*, which, in their chemical nature, are allied bodies, being compounds of fatty acids with complex alcohols other than glycerine, sustain very different relations to the life of the plant. Instead of serving as reserve food-materials, they appear to possess no nutritive value whatever, but are purely protective in their function. They occur as excretions on the cuticularized epidermis of many plants. The "bloom" of certain fruits is of this nature, and the glaucous appearance of the leaves and stems of many plants is due to the same cause. The parts covered by it are protected from wet, and so from the spores of destructive fungi; it doubtless serves also to check excessive evaporation from the plant. Occasionally, as in the case of the Wax Palm of New Granada and the Wax Myrtle of our New England coast, the secretion is sufficiently abundant to be of commercial importance.

Volatile Oils. Ethereal or volatile oils bear some resemblance in their appearance and physical properties to the fixed oils or fats, but they differ from them both in chemical nature and in origin. Moreover, they are incapable of serving as reserve food materials, and are of no nutritive value to the plant. They are more or less volatile at ordinary temperatures, are slightly soluble in water (to which they communicate their taste and odor), are not converted into soaps by the action of alkalies, and they may be completely volatilized by heat without undergoing chemical change. Some of them are of service to the plant in protecting it against injurious insects or other animals, and perhaps also against destructive fungi, while others, as the floral perfumes, are useful, as we have already seen, in attracting insects to flowers, and so in effecting cross-fertilization by their agency. They occur in solution in the cell-sap of most flowering plants, and are often excreted along with resins into secretion reservoirs.

They may be classified according to their composition into *hydrocarbons*, represented by common oil of turpentine ($C_{10}H_{16}$), oil of cubebs, oil of copaiva, etc.; *oxygenated essences*, as the oils of anise ($C_{10}H_{12}O$), bergamot, rose, sandalwood, etc.; *nitrogenated essences*, as the oils of cherry-laurel leaves and bitter almonds (C_7H_6O, HCN); and *sulphureted essences*, as the oils of assafœtida, mustard (C_3H_5, CNS), and horse-radish. Many of the natural essences are mixtures of two or more different compounds.

Closely related to these are the *camphors*, like common camphor ($C_{10}H_{16}O$), Borneo camphor ($C_{10}H_{18}O$), etc. They are often found associated with the volatile oils, and appear to be derived from them by oxidation.

Resins, Oleo-resins, Gum-resins, and Balsams. Resins are very common constituents of plants. They appear to be in the nature of excretory products, formed by the decomposition of tannin, or other glucosidal bodies. They are either produced in special cells or groups of cells called glands, occurring on the surface of plants, or forming the terminal cells of glandular hairs, or else in internal cells which pour their secretions into intercellular spaces called secretion reservoirs. They are, for the most part, amorphous, more or less transparent, readily fusible substances, which cannot be volatilized without change, and which are soluble in alcohol and in the volatile oils, but not in water. Guaiac, mastich and common rosin may be taken as examples. When mixed with volatile oils, as in Venice and common turpentines, they are called *oleo-resins;* if they contain benzoic or cinnamic acids, either with or without volatile oils, they are called *balsams;* and if mixed with gums, they are termed *gum-resins*. The last are often constituents of the milk-juice of plants. Benzoin, Styrax and Peru Balsam are examples of the balsams, and Gamboge, Myrrh, Galbanum and Ammoniac of gum-resins. Caoutchouc and Gutta-percha are peculiar resinous constituents of the milk-juice of some plants.

Glucosides. The glucosides are compounds found in solution in the cell-sap, or deposited in the cell-walls of plants. Their peculiarity consists in the fact that under the influence of unorganized ferments like ptyalin, emulsin, myrosin, etc., or by other means, they are decomposable into glucose or some similar sugar, and another substance capable of still further decomposition. Their molecules are complex, and most of them are composed of carbon, oxygen and hydrogen, but some few of them contain nitrogen in addition. Tannin ($C_{27}H_{22}O_{17}$), salicin ($C_{13} H_{18} O_7$), coniferin $C_{16}H_{22}O_8$), convolvulin ($C_{31}H_{50}O_{16}$), ericolin $C_{34}H_{56}O_{21}$), arbutin ($C_{25}H_{34}O_{14}$), daphnin $C_{31}H_{34}O_{19}$), menyanthin ($C_{22}H_{36}O_{11}$), hesperidin ($C_{22}H_{26}O_{12}$), parillin ($C_{14}H_{24}O_2$), and saponin ($C_{52}H_{86}O_{26}$) are examples of the former, while amygdalin ($C_{20}H_{27}NO_{11}$) and laurocerasin ($C_{40}H_{53}NO_{23}$) are examples of the latter. Some of them are acid in their reaction, while the majority of them are neutral to test paper. They are, for the most part, soluble in water. Many of them constitute active and important medicinal principles.

Compound Ammonias. These are complex bodies derived from proteid matter in the course of the destructive changes that are constantly taking place in the living plants, but beyond this general fact little is known of their origin. They all contain carbon, hydrogen and nitrogen and most of them, also, oxygen. Chemically, they are either amines or amides. To this class of compounds belong the

Alkaloids. These are potent principles, some of them forming the most valuable of medicines, and others the most dangerous of poisons. Like the alkalies, they combine with acids to form salts, and their solutions restore the blue color to reddened litmus, whence the name, alkaloid. They are found in considerable variety, though a single species of plant seldom produces more than one or a few different kinds, and many plants do not appear to possess them at all. It has not been ascertained that they are of any service to the plant, except perhaps as a means of defense against predacious animals and parasitic fungi. They may even be injurious to the plants which produce them. The Poppy, for example, may be poisoned by its own alkaloid, morphine. It is perhaps for this reason that they are not commonly found in large quantities in those parts of the plant where the vitality is the greatest, but are accumulated in the less actively growing parts of the bark, in fruits and in seeds,—parts destined sooner or later to become detached from the plant,—and are thus gradually gotten rid of. In the plant, we usually find them in combination with organic acids.

There are two groups, the *non-volatile*, which contain oxygen and are solid at ordinary temperatures, and the *volatile*, which do not contain oxygen and are liquid at ordinary temperatures. The former are amides; the latter, amines.

Among the better known non-volatile alkaloids are *aconitine* ($C_{33}H_{43}NO_{12}$), obtained from Aconitum napellus ; *brucine*, ($C_{23}H_{26}N_2O_4$), obtained from the seeds of Strychnos nux-vomica ; *caffeine* ($C_8H_{10}N_4O_2$), obtained from Coffee, Guarana and Tea ; *quinine* ($C_{20}H_{24}N_2O_2$), obtained from the Cinchona barks ; *morphine* ($C_{17}H_{19}NO_3$), obtained from the milk-juice of the Poppy ; and *strychnine* ($C_{21}H_{22}N_2O_2$), obtained from the seeds of various species of Strychnos.

Nicotine ($C_{10}H_{14}N_2$), obtained from Tobacco ; *Conine* ($C_8H_{15}N$), obtained from the Poison Hemlock ; and *sparteine* ($C_8H_{13}N$), obtained from the Broom, are examples of volatile alkaloids.

Amides not Alkaloidal. Not all the amides found in plants have the nature of alkaloids. Some possess no alkaline reaction ; and moreover are not in the nature of waste products, but sustain important relations to the life of the plant. Among the more important of these are *asparagin* ($C_4H_8N_2O_3$), found in Asparagus, Marsh-mallow, Eunonymus, the Leguminosæ, and in many other plants ; *glutamin* ($C_5H_{10}N_2O_3$), found in the Beet ; and *tyrosin* ($C_9H_{11}NO_3$) and *leucin* ($C_6H_{13}NO_2$), both found in germinating seeds. They occur in solution in the cell-sap. Asparagin is one of the forms in which nitrogenous matters are transferred from one part of the plant to another. Reserve proteid is changed into it and transferred to growing parts. where it is again converted into protoplasm. It is probable that the others mentioned have similar uses.

Unorganized Ferments. These are nitrogenous compounds whose chemical nature is not well understood, but they appear to be closely related to the proteids. Their peculiarity consists in their power to bring about important chemical changes in substances with which they are in contact. On this account, they are of great importance in the economy of vegetable life. In their nature and action they are similar to the animal ferments, ptyalin, pepsin and trypsin. Some of them, as *diastase* and *maltin*, which occur in germinating cereals and also elsewhere in plants, have the power to convert starch into dextrine and grape-sugar ; others, as *emulsin*, found in bitter almonds and some other seeds of rosaceous plants, and *myrosin*, found in the seeds of black mustard, have the power to decompose glucosides with the formation of grape-sugar ; a ferment called *invertin*, found in yeast, has the power to change common cane sugar into invert sugar; and still other ferments, as *papain* or *papayotin*, obtained from the green fruit of the Paw-paw, and a ferment similar to pepsin, found in the glandular hairs of the Sundew, have the power to transform proteid matters into peptone.

Neutral Principles. Under this head are included numerous other neutral organic compounds, found in solution in the cell-sap, that cannot properly be included under any of the above heads. The term is not here used in any strict scientific sense, but simply as one of convenience, to include a heterogeneous collection of compounds—some quite complex, others relatively simple—whose chemical relations are not yet well determined. Some authors also include under this head the neutral glucosides and the non-alkaloidal amides.

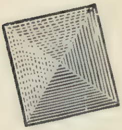


FIG. 384.

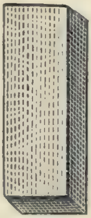


FIG. 385.

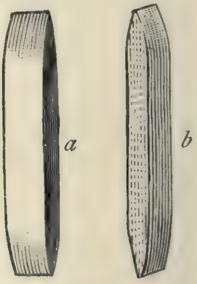


FIG. 386.

FIG. 384.—Calcium oxalate crystal from the petiole of Begonia. Magnified about 500 diameters.

FIG. 385.—Calcium oxalate crystal from the leaf of Agave. Magnified about 300 diameters.

FIG. 386, *a*, *b*.—Another form of crystals from Agave. Magnified about 200 diameters.

Here are classed such principles as *aloin* ($C_{15}H_{16}O_7$), derived from Socotrine aloes; *quassin* ($C_{10}H_{12}O_3$), derived from the wood and bark of Picraena excelsa and of Quassia amara; *santonin* ($C_{15}H_{18}O_3$), derived from Levant Worm-seed, and *picrotoxin* ($C_9H_{01}O_4$), derived from the seeds of Animirta paniculata, a plant belonging to the Moonseed family. Some of these principles are harmless, others are valuable medicines, and still others, like picrotoxin, are active poisons. Although their origin and uses to the plant are not thoroughly known, they are probably, most of them, to be regarded as waste products of tissue metamorphosis.

Mineral Substances. The cell-sap contains many inorganic substances in solution, such as oxygen, nitrogen, carbon dioxide, silica, and salts of potassium, sodium, calcium, magnesium and iron. Silica and salts of calcium, as has already been stated, are often deposited, either in the amorphous or crystalline form, in the substance of the cell-wall. But, besides these, crystals of mineral matter are often found in the interior of cells.

The most common of these are calcium oxalate and calcium carbonate, but calcium phosphate, calcium sulphate and silica are sometimes, though rarely, found among the cell contents. Crystals of calcium oxalate are by far the most common, and they are found in a great variety of forms.

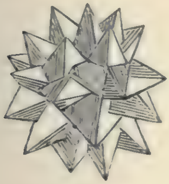


FIG. 387.

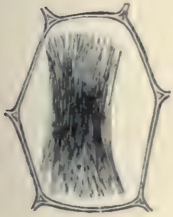


FIG 388.

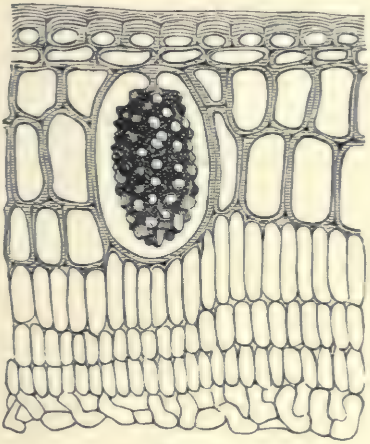


FIG. 389.

FIG. 387.—Mass of sphere-crystals from the underground stem of Aralia nudicaulis. Magnified about 375 diameters.

FIG. 388. Cell containing a bundle of raphides from the rhizome of Trillium grandiflorum. Magnified about 250 diameters.

FIG. 389.—Portion of cross-section of leaf of Ficus elastica, showing large cell containing a cystolith. Magnified about 250 diameters.

They may occur singly or in clusters. Figures 384 and 385 represent some single forms from the petiole of Begonia and the leaf of Agave, respectively; Fig. 386, another form from the leaf of Agave; Fig. 387, a mass of sphere-crystals from the underground stem of *Aralia nudicaulis*, and Fig. 388 represents a bundle of raphides, or needle-like crystals, of the same substance, from the rhizome of *Trillium grandiflorum.* The curious stalked bodies called cystoliths, that occur in large cells just beneath the upper epidermis in the leaf of *Ficus elastica*, Fig. 389, and in some other plants, consist mainly of calcium carbonate.

Besides the classes of substances already described as occurring in the cell-sap, or deposited in the cell-walls of plants, there are various others of less importance, such as certain coloring matters, aromatic compounds and decomposition products, which are as yet too imperfectly understood to be properly classified.

PRACTICAL EXERCISES.

1. Strip off the epidermis from the upper side of one of the fleshy scales of the onion bulb, and examine it with a magnifying power of about 200 diameters. It will be seen to consist of a layer of elongated cells. The cell-walls, though transparent, are distinctly visible, but the protoplasm is difficult to detect. With care, however, the nucleus and some minutely granular matter may be seen in the interior of the cell. Now treat the tissue with a drop of nitric acid, and then with a little ammonia. The protoplasm will be rendered distinctly visible as a granular mass in the interior of the cell. The re-agents have also caused it to shrink away from the cell-wall, which now appears thinner than before, because the primordial utricle is no longer in contact with it.

Take now a fresh portion of the same tissue, treat it for a few moments with a strong solution of iodine, rinse it for a moment in clean water, and examine with the same magnifying power as before. The cell wall will be but slightly stained, the protoplasm will have acquired a distinct brownish-yellow color, and the primordial utricle, with its two layers, and the nucleus, nucleoli and vacuoles, will be distinctly recognized.

Now bring a drop of strong sulphuric acid into contact with the iodine-stained tissue, and immediately observe the result. The cell-wall will be stained blue. The sulphuric acid first converts it into amyloid, a substance closely allied to starch, and the iodine then reacts upon it to produce the blue color. This constitutes one of the best tests for cellulose. The cell wall will in a short time be completely dissolved by the acid, but the protoplasm, though finally destroyed, disappears much more slowly. Lastly, draw a few of the cells, so as to show the structure and relation of parts.

2. Take a small piece of the green leaf of the Fresh Water Eel-grass, Valisneria spiralis, and examine the cells with a magnifying power of 300 or 400 diameters. Among the cell contents will be seen numerous green granules, the chlorophyll-bodies. They are in motion, being conveyed around the interior of the cell-walls by means of the currents in the protoplasm. Study these movements with care, and then treat the cells with iodine solution. After a few minutes, wash off the superfluous iodine and then examine. The protoplasm has not only been stained, but its movements have been stopped and its life

destroyed. It will be observed, also, that the chlorophyll-bodies have been stained a brown color similar to, but owing to their density, a deeper brown than that of the protoplasm.

Soak a portion of a fresh leaf for twenty-four hours in strong alcohol, and then observe the effects. The protoplasm has been killed, and has shrunken so that the primordial utricle is no longer in contact with the cell-wall. Now put this, together with a small portion of the fresh leaf, in borax-carmine solution for a few hours, and then observe the results. The nucleus and protoplasm of that portion treated with alcohol will be found stained, while the living protoplasm has not taken the staining material. This illustrates an important difference between living and dead protoplasm.

Protoplasmic movements similar to those seen in Vallisneria may be studied in the young stinging hairs of the Nettle, in the blue, moniliform hairs borne on the filaments of the Virginia Spiderwort, and in the leaves and large internodal cells of Chara and Nitella.

For different forms of chlorophyll-bodies, study the leaves of any common moss, thin sections of the leaves of Begonia, and filaments of Zygnema and Spirogyra. The latter are common pond-scums, popularly known as brook-silks, Figs. 372 and 373. Make drawings illustrating each study.

3. Young cells for study may be found near the growing apex of stems and roots. Thin sections of the tip of the radicle of the germinating Bean or Pea, or of the sub-apical portion of a young root of the Indian Corn, afford good examples. Study the sections first in a drop of pure water ; then afterward stain them with iodine ; examine and make drawings of them. If the thin cell-walls cannot be distinctly seen by this treatment, clear one of the sections by soaking it for a while in five per cent. solution of potassium hydrate, and then afterward treating it with strong acetic acid, and finally examining it in the solution of potassium acetate thus produced.

4. For the study of starch grains, soften the fruits of any of the cereals, as Indian Corn, Rice, Wheat, Oats or Barley, and seeds of the Leguminosæ, as Peas and Beans, in warm water ; make thin sections of them, and examine them with a power of from 150 to 500 diameters. Examine, also, thin sections of the Potato tuber and the fleshy rhizomes of Canna and Ginger in the same way.

Observe the position of the nucleus and the character of the markings.

Treat the grains with a dilute solution of potassium hydrate by putting a drop of the solution at one edge of the cover-glass and drawing it under by means of a bit of blotting paper placed at the opposite edge, and immediately examine. Observe that they swell, and at first the markings are rendered more distinct, but afterward, by the imbibition of more water, they disappear, and finally the grains themselves pass into solution.

Stain another set of sections with dilute iodine solution, and observe that the starch grains assume a violet-blue color. They may thus readily be distinguished from other cell-contents.

Make careful drawings and measurements of the grains of several different kinds of starches.

Treat a small quantity of Potato or Corn starch with saliva, keeping the mixture at the temperature of about 90° F. for a few hours, and then examine. Only the transparent skeletons of the former grains will be left, and if these be treated with iodine, no blue coloration will be developed. The granulose has been dissolved, leaving only the starch cellulose.

5. For the study of inulin, make some moderately thin sections of the roots of the Dahlia, Dandelion or Chicory that have been gathered in the autumn ; soak them for a few hours in strong alcohol, and then examine them. Sphere crystals of inulin, which may be distinguished from starch and mineral crystals by the fact that they stain a yellowish color with iodine, will be found in some of the cells.

6. For the study of aleurone grains and crystalloids, make some thin sections of the flesh of the seed of the Castor Oil plant or of the Brazil nut ; soak the sections for twenty-four hours in alcoholic solution of corrosive sublimate, so as to render the proteids insoluble ; stain them in solution of eosin ; then place them on a glass slip in solution of potassium acetate, and examine them. Some of the aleurone grains will be observed to be amorphous, and others will be seen to contain crystalloids and globoids. Draw some of the different forms.

Treat a fresh section of the same seed with concentrated solution of potassium hydrate, and then afterward dilute the solution with water by running a little under the edge of the cover-glass, and then immediately observe. A slight swelling of the crystalloid will be observed when the potassium hydrate is added, but when water is added it swells rapidly and dissolves. All the other proteids are similarly affected, but mineral crystals, if present, remain unchanged. Aleurone grains may also be studied by laying the freshly cut sections in a drop of water and immediately examining. The water does not at once disintegrate the aleurone grain, owing to the oil present. If now a drop of absolute alcohol be run under the cover glass, the crystalloid within the aleurone grain will come distinctly into view.

Fine cubical crystalloids may also be found in the outer portion of the potato tuber.

7. For the study of plant crystals, thin sections of the stems, leaves or roots of the following plants may be made :

Raphides are abundant in the Evening Primrose, the Calla Lily, the Indian-turnip and most other members of the Arum family, as well as in many liliaceous plants.

Sphere-crystals are abundant in medicinal Rhubarb, in the Yellow Dock and in the Hollyhock and most other Malvaceous plants.

Other forms may be found in the stems of the Cactuses, in the stems and leaves of the Begonias, in the leaves of the Century Plant, etc.

Crystoliths of great beauty are obtained by making thin cross sections of the leaves of the common Nettle and of Ficus elastica. They are also found in the leaves of many other members of the Urticaceæ, and also in some Acanthaceæ.

Plant crystals may be studied to advantage by means of polarized light, and a magnifying power of from 200 to 500 diameters should be used.

Apply the following tests to determine the nature of the crystals:

Acetic acid has no effect on silica and calcium oxalate, but calcium carbonate dissolves with effervescence. Hydrochloric acid has no effect on silica, but dissolves calcium oxalate without effervescence, and calcium carbonate with effervescence.

Make careful drawings of the different forms of crystals which you observe.

CHAPTER II.—THE FORMATION OF CELLS.—PLANT TISSUES.

Most cells have the power of reproduction, or of giving origin to new cells. This may take place in one of three principal ways: By *division*, by *rejuvenescence*, and by *union*.

1. *The Division of Cells.* There are three different ways in which this may take place. The most common mode is by *fission*, or the separation of the cell into two equal portions. This may occur in either of the two following ways:

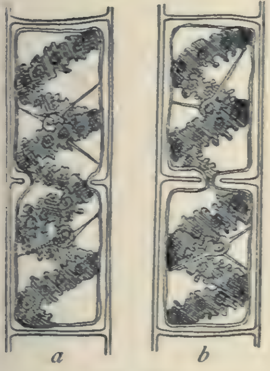


FIG. 390.

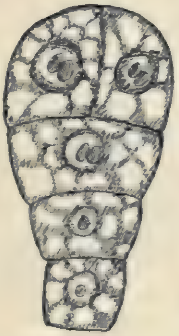


FIG. 391.

FIG. 390., *a* and *b*.—Earlier and later stages, respectively, in the cell divisions of Spirogyra. Magnified about 500 diameters.

FIG. 391.—Young embryo of the Onion, showing fission of cells. Magnified about 400 diameters.

a. A constriction may take place in the middle of the cell, and, along the plane of this constriction, the cell-wall may grow inward until the cell contents become separated into two equal portions. This mode has been observed in some of the lower Algæ, Fig. 388.

b. A delicate partition of cellulose may at once be formed through the middle of the cell. This is the usual mode by which tissues are formed and growth takes place in all the higher plants. It is illustrated in Fig. 391, which represents the growing embryo of the Onion. The terminal portion has just divided into two cells, and these and the one below them are preparing to divide again, as is evidenced by the fact that the nucleoli have already divided.

In most cases of cell fission, the nucleus appears to play an important part, the progressive changes through which it passes, just previous to the formation of the membranous separating partition, being exceedingly complicated and interesting. Some of the successive stages in these changes, as they occur in the hairs taken from the young filaments of Tradescantia Virginica are illustrated in Fig. 392. The illustrations are taken from Strasburger. In some plants, however, as in Cladophora glomerata, a common fresh-water alga, where the cells, when mature, are multinuclear, the nuclei increasing by division within the

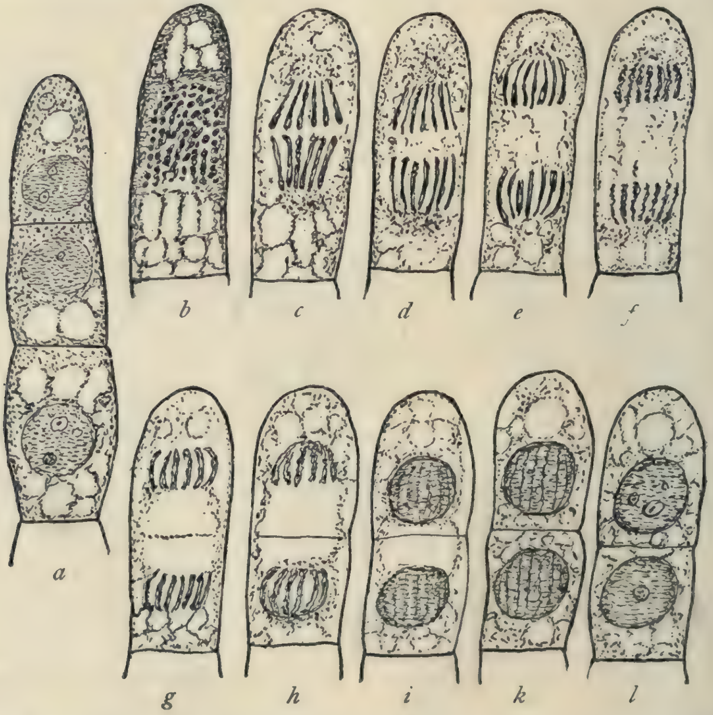


Fig. 392.—Tradescantia Virginica. Process of division in the cells of the staminal hairs. *a*, terminal portion of filament with three cells, the lower with a resting nucleus; the upper two cells have just been formed by division. *b*, cell with coarsely granular nucleus, preparing for division. *c* to *l*, successive stages of division followed in the same cell. Magnified 540 times. After Strasburger.

cells, the nuclear division appears to bear no causal relation to cell-division in the same plant.

A second mode of cell division is that of *gemmation*, or budding. In this, a minute protuberance is first formed on the surface of the cell; it gradually increases in size until as large, or nearly as large, as the parent cell, when ordinarily it separates from the latter and becomes an independent organism. Sometimes, however, they remain attached to each other for a time, forming small chains, but ultimately become independent. This mode is observed only among the Yeast plant and its relations. See Fig. 393.

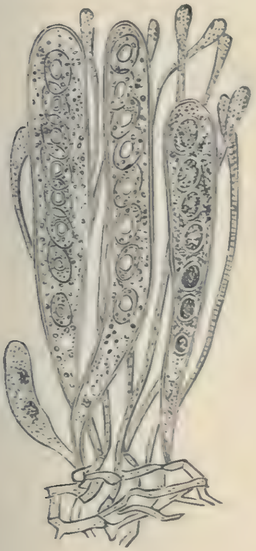


FIG. 394.

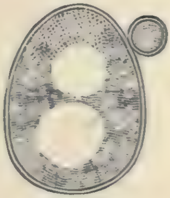


FIG. 393.

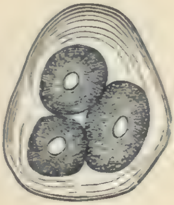


FIG. 395.

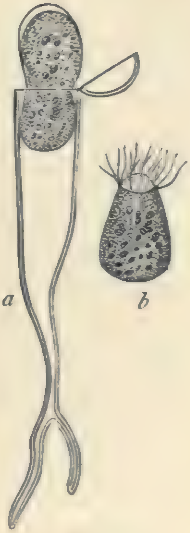


FIG. 396.

FIG. 393.—Budding Yeast cell. Magnified about 2,500 diameters.

FIG. 394.—Small portion of sporocarp of Cup Fungus, showing asci containing ascospores. Magnified about 350 diameters.

FIG. 395.—Mother cell from the anther of Tropeolum, showing the formation of pollen grains by internal cell-formation. Magnified about 600 diameters.

FIG. 396.—*a*, Young plant of Oedogonium, reproducing itself by rejuvenescence: *b*, the escaped protoplasm, after it has acquired cilia and the power of locomotion. Magnified about 350 diameters.

A third mode is by *internal cell-formation*. In this case the protoplasm within the parent cell-wall breaks up into two or more rounded masses, each of which eventually acquires a cell-wall of its own, and escapes from the parent cell by the rupture or decay of the old cell-wall. In this way ascospores are formed in Lichens and in some Fungi, Fig. 394, and pollen grains in the interior of the anther, Fig. 395.

2 *Rejuvenescence of Cells.* This consists of the aggregation of the protoplasm of the cell into a rounded mass, its escape through the cell-wall, and the subsequent formation for itself of a new cell-wall. Commonly, during the period which intervenes between the escape from the old cell and the formation of a new cell-wall, the protoplasm is endowed with the power of locomotion, and moves about either in an amœboid manner, or by means of cilia. This mode has been observed only among some of the lower forms of plant life, Fig. 396.

3. *The Union of Cells.* This consists in the coming together and blending of the protoplasms of two distinct cells to form a new one. This mode of new cell formation is confined to the reproductive process, and is essentially what constitutes reproduction in all plants that reproduce by a truly sexual process. There are two principal varieties of it:

a. That in which the uniting cells are to all appearance alike. This is observed only among certain low forms of vegetable life, as in Mucor (a mould) and in the Diatoms, Desmids, Mesocarpus and Spirogyra, all simple forms of algæ, Fig. 397. This process is called *conjugation.*

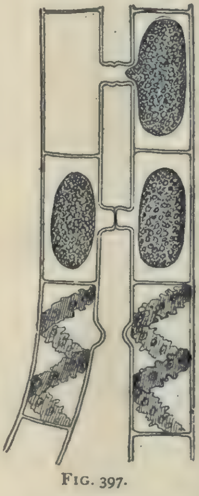


FIG. 397.

FIG. 397.—Portions of two filaments of Spirogyra, showing cell formation by conjugation. The protoplasm from the upper cell of the filament to the left has passed over into the corresponding one to the right.

The same process, in an earlier stage, is shown in the two cells below these, and in the lowest ones it has just begun, by the formation of two protuberances on the adjacent sides of the cells. Magnified about 250 diameters.

b. That in which the uniting cells are unlike. In this case one cell (the male or sperm cell) is commonly not only smaller, but more active than the other, which is called the female or germ cell. This mode is illustrated in the reproduction of all the higher plants, and is called *fertilization.*

It will be seen that in all these cases new cells are formed from pre-existing ones; that living organisms are derived from antecedent living organisms. Such a thing as the spontaneous generation of living protoplasm from inorganic matter has never yet been observed.

PLANT TISSUES.

While it is true that all the essential phenomena which we call "vital" are manifested within the compass of a single cell, it is true, also, that the manifestation is feeble in comparison with that exhibited by cell aggregates, where there is division of labor among the cells. All the higher plants are such aggregates or collections of cells. The Rose-bush, for example, is made up of millions of them, and its life is not the mere aggregate life of cells precisely alike, but rather that of sets of cells that have grown to differ from each other in form and function, some being specialized for one use, and others for another, but all subserving the life of the whole organism. These cell-groups, which differ from each other in ways more or less important, but each of which is composed of similar cells, are called *tissues*. The lowest plants cannot be said to possess tissues, since they are either one-celled or are collections of precisely similar cells; but as we study plants in the ascending scale, we find a more and more complete differentiation of the cells, until, in the ferns and flowering plants, we find a great variety of tissues, the individual cells of which differ more or less markedly from the typical cell already described.

It must be remembered, however, that all these tissues originate from a single cell, and that each cell of the mature plant, however great its deviation from the typical form, approximates it very closely in the early stages of its development.

Tissues may conveniently be classified into four series, the *parenchymatous*, the *prosenchymatous*, the *sieve*, and the *laticiferous* series.

I.—Parenchymatous Series. The tissues of this series all agree in being less modified, in shape at least, from the primitive or typical form of cells than the other tissues. They mostly retain to maturity the proper character of cells; that is, they possess protoplasm and a nucleus, and possess the power of cell-division. In some cases they become elongated and somewhat fibrous in appearance, but more commonly they are not much longer than broad, and have their ends square or rounded rather than oblique or tapering. Many of the series are thin-walled cells, but others become thickened by cellulose, cutinous or ligneous deposit. The following are the principal kinds:

(1) *Parenchyma* proper, or soft tissue, is at once the most abundant and the least modified of all the vegetable tissues. The walls are thin, and frequently, though not always, composed of unmodified cellulose. In form they are commonly spheroidal or polyhedral, and the longitudinal diameter rarely much exceeds the transverse.

It includes most of the soft tissues of plants, such as the green cells of the leaf, the thin-walled cells of the pith, a considerable portion of the cells of the bark, frequently those of the medullary rays, etc. Not infrequently the cell-walls are so unequally thickened as to present the appearance of markings or sculpturings of various kinds; indeed, they are seldom of uniform thickness, but commonly their membranous character and transparency makes them appear so. Forms of pitted parenchyma are shown in Figs. 399 and 400.

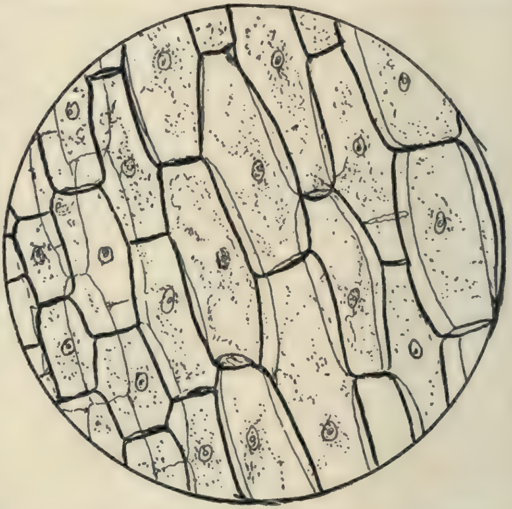


FIG. 398.—Parenchyma cells from the root of Aspidistra, magnified 155 diameters. They are shown in longitudinal view.

The very loosely arranged green cells that occur in the interior of leaves are called *spongy* parenchyma; the more compactly arranged and somewhat elongated ones found next the upper epidermis of most flattened leaves, are called *palisade* parenchyma; parenchyma like that illustrated in Fig. 399, is called *pitted* parenchyma; that in which the cells take star-shaped forms, as shown in Fig. 365, is called *stellate* parenchyma;

and the green cells with internally folded walls, found in the interior of Pine leaves, are called *folded* parenchyma (see Fig. 459).

(2) *Collenchyma*, or thick-angled tissue, is closely related to ordinary parenchyma, but the cells are more elongated, often five or six times longer than broad, prismatic in shape, and thickened at the angles. The thickenings, though often conspicuous, are usually not lignified, and the cells contain protoplasm and more or less chlorophyll. They are never found elsewhere than in close proximity to the epidermis, or rarely in similar relations to the endodermis, and one of the uses which they subserve is evidently that of giving strength and resistance to these portions of the plant. Every gradation is observed between this and ordinary parenchyma on the one hand, and fibrous tissue on the other. Sometimes it forms a continuous zone beneath the epidermis, as in the petiole of the Summer Grape and of the Begonia; at others, it occurs in longitudinal bands, as in the stems of the Yellow-Dock and Cow-parsnip. The tissue is illustrated in Figs. 401 and 402.

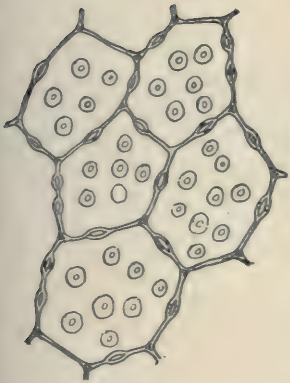


FIG. 399.

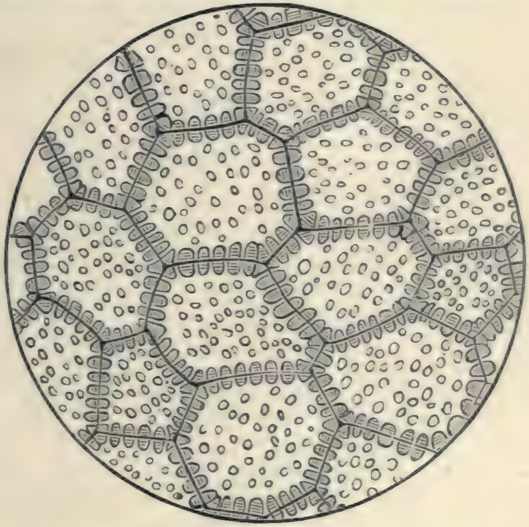


FIG. 400.

FIG. 399.—Pitted Parenchyma cells from the leaf of a Pine: magnified 300 diameters.
FIG. 400.—Pitted Parenchyma from the pith of the stem of Asimina triloba: magnified 480 diameters.

(3) *Sclerotic tissue.* The cells of this tissue are commonly called stone or grit cells. It differs from ordinary parenchyma in having the walls of the cells excessively thickened—so much so, frequently, that the cavity of the cell is nearly obliterated. Every gradation, however, may be observed between these and ordinary parenchyma cells. The cells represented in Fig. 400, though still properly called parenchyma, are verging

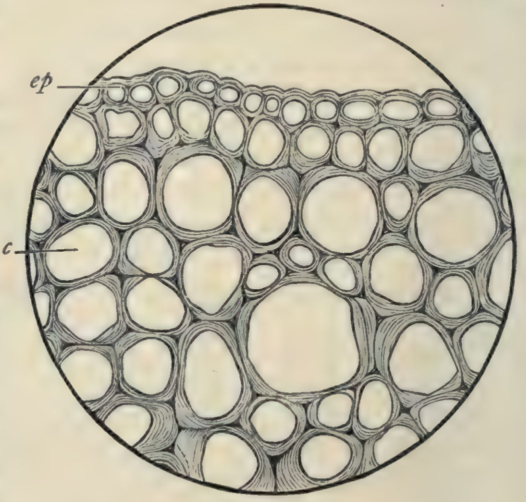


FIG. 401.

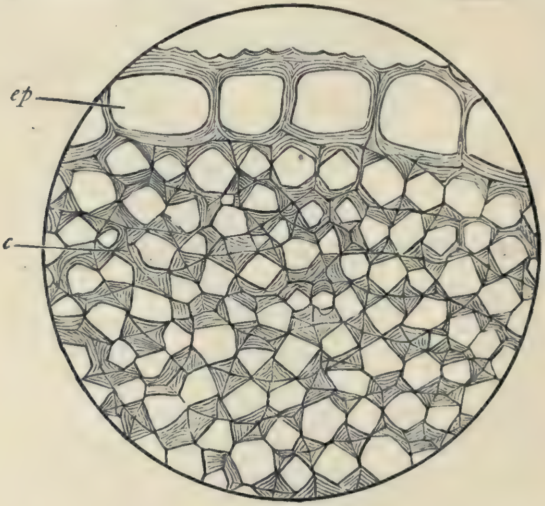


FIG. 402.

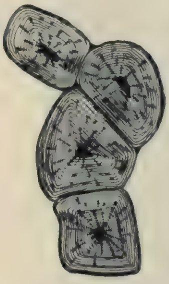


FIG. 403.

FIG. 401.—Portion of epidermis and sub-lying collenchyma from the petiole of the Summer Grape. Transverse section: *ep*, epidermis; *c*, collenchyma cells. Magnified 280 diameters.

FIG. 402.—Portion of epidermis and collenchyma from stem of Rumex crispus. Transverse section, magnified 480 diameters: *ep*, epidermis; *c*, collenchyma.

FIG. 403.—Sclerotic cells from the root of Apocynum androsæmifolium; magnified about 225 diameters.

toward the condition of stone cells. In sclerotic tissue the cell-wall is usually lignified, and the thickening is in layers, presenting the appearance of concentric rings. There are also delicate tubes or pore-canals radiating from the cell-cavity to the outer portion of the cell-wall.

These are the cells which give the great hardness to the outer coats of many seeds, and the shells of nuts. They constitute the gritty particles that occur in the flesh of some fruits, as that of the Pear, and they occur in the pith of the Apple, Menispermum Canadense, and Hoya carnosa, in the cortex of the root of the Dogbane, etc. They, are, in fact, seldom entirely absent from the more highly organized plants. See Fig. 403.

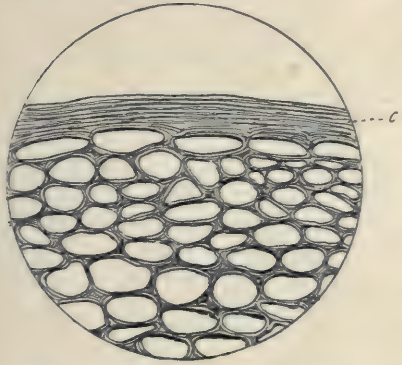


Fig. 404.—Portion of transverse section of exterior part of stem of Menispermum Canadense, showing cuticle, *c*, greatly thickened, and sub-lying collenchyma tissue. Magnified about 375 diameters.

(4) *Epidermal Tissue.* The epidermis constitutes the primary covering of the plant. It usually consists of one, but sometimes of two or three layers of cells. The component cells are so placed with reference to each other, that no intercellular spaces exist excepting where the stomata and water-pores occur, and commonly they have that portion of the cell-wall which faces outward, considerably thickened and cutinized. When viewed from the upper or under surface, they often appear sinuous or irregular in outline, but sometimes they are straight-sided and regular. In many plants, also, they are somewhat elongated in the direction of the length of the organ. This is especially true of the cells which cover the veins on the under surface of leaves. In such cases they are not only considerably elongated but often, also, oblique-ended or fusiform. Different forms of epidermal cells are shown in Figs. 405 and 406.

Stomata are modified epidermal cells, usually crescent-shaped, occurring in pairs, and so placed that the concave sides face each other, leaving a small opening between them. Each cell of the stoma is called a *guard-cell.* See Figs. 407 and 408.

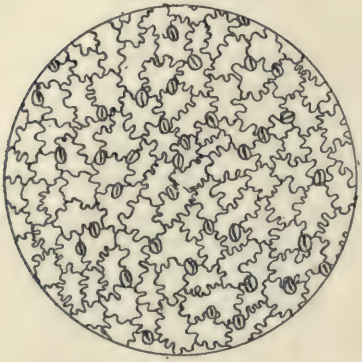


FIG. 405.

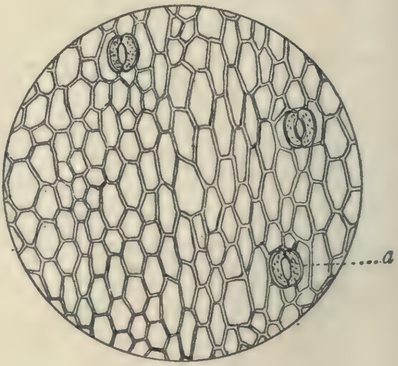


FIG. 406.

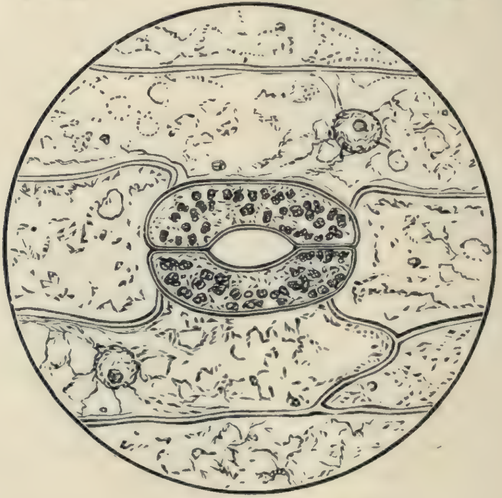


FIG. 407.

FIG. 405.—Portion of lower epidermis of leaf of Gentiana alba, showing lobed epidermal cells and numerous stomata. Magnified about 65 diameters.

FIG. 406.—Portion of upper epidermis of leaf of Sanseviera. *a*, one of the stomata. Magnified about 100 diameters.

FIG. 407.—Small portion of epidermis of Tulip leaf, showing one of the stomata and portions of adjacent epidermal cells, viewed from above. Magnified 480 diameters.

Stomata are also shown in Figs. 405 and 406. The opening between the cells is increased or diminished by certain external agencies, as light and the quantity of moisture in the air, and they thus serve to control the amount of evaporation from the plant.

Water-pores are also openings in the epidermis, bearing some resemblance to stomata, but differing from them in the fact that the guard-cells are immovable, and the opening, therefore, does not increase or diminish, and also in the fact that water, instead of gaseous matter, commonly fills the orifice or oozes out upon the surface. Their distribution is also different from stomata. While the latter are most abundant between the veins on the under surface of leaves, water-pores occur at the extremities of veins on the margin of the leaf and usually toward the upper side. Fig. 409.

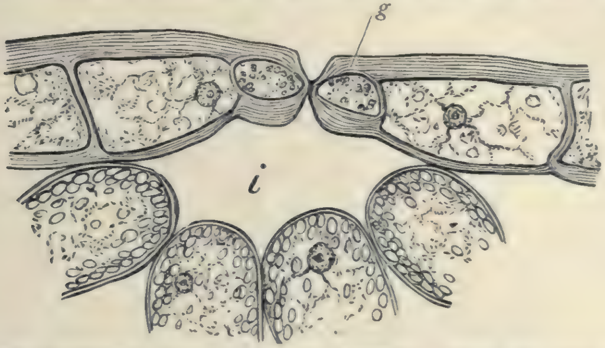


FIG. 408.—Small portion of transverse section of Tulip leaf, giving sectional view of one of the stomata. *g*, one of the guard-cells; *i*, large intercellular space beneath stoma. Magnified 480 diameters.

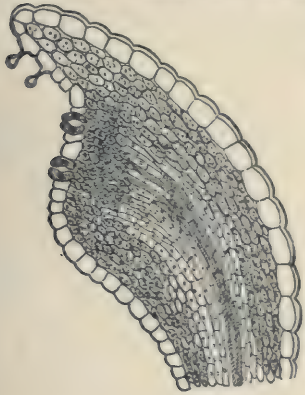


FIG. 409.

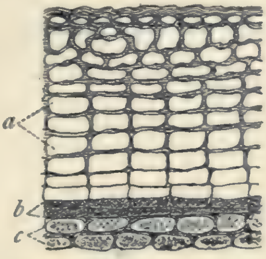


FIG. 410.

FIG. 409.—Section of leaf of a species of Saxifrage, showing two water-pores at the extremity of a vein. Above them are two hairs, to which usually a deposit of calcium carbonate clings, on evaporation of the water excreted by the pores. Modified from Vines. Magnified about 50 diameters.

FIG. 410. Section of branch of Currant, showing cork cells, and the way they are formed. *c*, chlorophyll bearing parenchyma; *b*, cork-cambium; *a*, mature cork cells. Magnified about 275 diameters.

Hairs, also are mostly modifications of the epidermis. They may be thin-walled, like ordinary parenchyma, or become cutinized or hardened by deposit of mineral matters, such as silica and calcium carbonate, or by sclerosis or excessive thickening of the walls of their component cells, they may become hardened into prickles. In the latter case, they are commonly strengthened by an outgrowth of cells from tissues underlying the epidermis.

Epidermal cells usually contain a nucleus and watery, transparent and commonly colorless protoplasm. In some cases, however, the cells are tinted by coloring matters in solution in the cell-sap. Ordinary epidermal cells are usually destitute both of chlorophyll-bodies and starch-grains, but exceptions occur in the leaves of some thin-leaved plants growing in shady places and in the leaves and stems of many aquatics. The guard-cells of the stomata nearly always contain chlorophyll-bodies, and are rich in protoplasm. Hairs, when mature, very often lose their protoplasmic contents and become filled with air.

(5) *Endodermal Tissue*. This tissue consists of a single layer of compactly arranged cells which surround and form a protecting sheath to either single fibro-vascular bundles or, more rarely, to groups of them. The cells composing it are usually elongated, four-sided prisms, with square or oblique ends and more or less cutinized cell-walls. The cutinization is usually most decided in the radial portion of the wall, or that which is common to adjacent cells of the tissue. This portion of the wall is also usually seen to be more or less wrinkled or folded when examined under a high power. See Figs. 435, 437, 438 and 441.

(6) *Cork* or *suberous tissue* consists of parenchyma cells, the walls of which have undergone the suberous modification. It is commonly formed beneath the epidermis of woody stems and roots, and ordinarily soon replaces the latter. It is also formed over the surface of wounds during the healing process. The cells are usually tabular in form, very compactly arranged in radial rows, and at maturity lose their protoplasm, becoming filled with air, Fig. 410.

II.—Prosenchymatous Series. To this series belong those tissue elements, or cell derivatives, which, at maturity, lose their nuclei and protoplasmic contents, and therefore their distinctively cellular character, and have their walls thickened by secondary deposit. They sometimes contain starch and traces of proteid matter, but take no active part in the nutritive processes of the plant. They serve it mainly for strengthening or support, and hence have been called mechanical tissues. They are serviceable also in conducting the sap. The elements of these tissues are for the most part elongated and oblique-ended or taperpointed, though exceptions to the rule are not wanting. Among the shorter forms transitions occur between them and sclerotic parenchyma, and between the fibrous forms and collenchyma every gradation may also be observed.

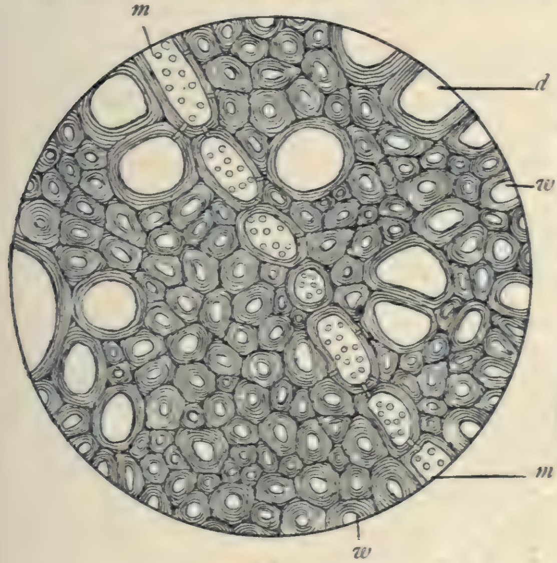


FIG. 411.

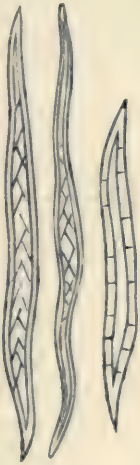


FIG. 412.

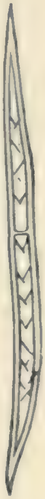


FIG. 413.

FIG. 411.—Portion of transverse section through woody part of stem of Pilocarpus pennatifolius. *m*, *m*, medullary ray cells; *w*, *w*, wood cells; *d*, a duct. Magnified 385 diameters.

FIG. 412.—Simple wood cells, isolated, and magnified about 200 diameters.

FIG. 413.—Wood cell with septum near the middle. Magnified about 200 diameters.

(7). *Wood or Libriform Cells.* These constitute the great bulk of the wood of most plants. They abound particularly in the stems of Dicotyledons, in the area between the pith and the bark. The cells are compactly arranged, long-fusiform in shape, rarely forked or lobed at one or both ends, more or less compressed laterally by mutual pressure, so as to appear angular in cross-section, and they are so placed together as to splice one over the other like the fibres of a rope, forming a hard and strong tissue, 411.

Wood cells exist in several modifications. The common or typical form is slender-fusiform, thick-walled, with a continuous cavity, and the walls sometimes marked with oblique or other markings, but frequently without them, Fig. 412. Another form, much less common, is distinguished by the possession of transverse septa. Fibers of this kind resemble the others in shape and in the thickness of their walls, and they are frequently marked by oblique slits, Fig. 413.

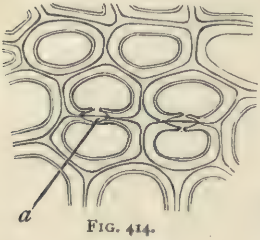


FIG. 414.

(8) *Tracheids*, or vasiform cells, are somewhat intermediate in their character between wood-cells and ducts.

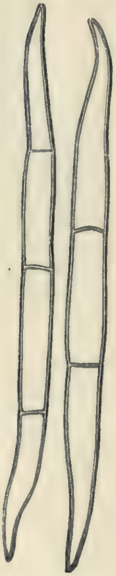


FIG. 417.

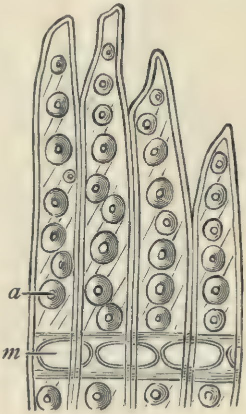


FIG. 415.

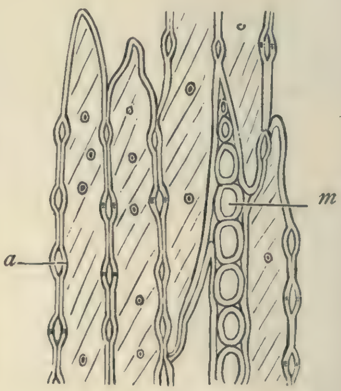


FIG. 416.

FIG. 414.—Transverse section of tracheids from White Pine. *a* is a bordered pit. Magnified about 250 diameters.

FIG. 415.—Longitudinal radial view, showing numerous bordered pits. *a*, a bordered pit; *m*, one of a row of medullary ray cells. Magnified about 175 diameters.

FIG. 416.—Longitudinal tangential section, showing medullary-ray cells and tracheids. In this view the pits appear lenticular in shape, and on the margins of the cells. *a* is one of the pits and *m* a medullary-ray cell. Magnified about 175 diameters.

FIG. 417.—Forms of wood parenchyma cells. Magnified about 200 diameters.

They differ from wood cells in having their walls less uniformly thickened, which gives rise to pitted, spiral, ring-like or other markings, in this respect resembling ducts, but they differ from the latter in the fact that they do not become confluent end to end into tubes. Where they occur in association with wood cells, as is most commonly the case, they are usually larger than these in transverse diameter, and have less tapering, merely oblique or even square ends, though there are some exceptions to these rules. When arranged end to end in linear series, they are indistinguishable from ducts, save by the imperforate transverse or oblique partitions.

In the Pines and other Gymnospermous plants a peculiar kind of tracheid takes the place of wood cells, and also for the most part, of ducts, giving to the wood of these plants peculiarities which enable us readily to distinguish it from that of other plants. If a radial section of the wood of the common White Pine be made, the elongated, fusiform cells of the woody zone will be seen to possess numerous rounded pits, each of which, in this view, looks like two circles, one within the other. They occur mostly on the radial faces of the cells, as is shown by comparing the radial, transverse and tangential sections. The comparison will also show us that the bordered pits, as they are called, are lenticular areas in the common wall between two adjacent cells. These areas have their lateral walls perforated centrally with a circular or oblong perforation. It is this which, in the radial view, gives rise to the optical impression of an inner circle in each pit. The perforation, however, does not extend, except in very old wood, completely through the common wall from one cell to the other, but there still remains stretched across the cavity of each area a delicate separating membrane. The structure will be understood by reference to Figs. 414, 415 and 416, which represent small portions, respectively, of transverse, radial and tangential sections of White Pine wood.

The parenchyma cells, with bordered pits, which occur immediately within the bundle sheath in the leaves of Pines, may be regarded as transition forms between ordinary parenchyma and the tracheids just described. Indeed, by some they are classed as tracheids. They have already been shown in Fig. 399.

Just as wood cells graduate into ducts, they also, on the other hand, graduate toward parenchyma, and we frequently find among the woody tissues rows of rather thin-walled cells, like those represented in Fig. 417, the end ones taper-pointed, the middle ones blunt-ended, and together forming a combination shaped like a wood cell. Such tissue is termed *wood parenchyma*, and the name happily expresses its intermediate character.

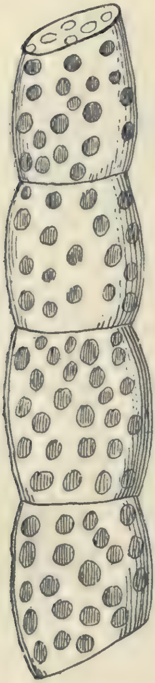


FIG. 418.

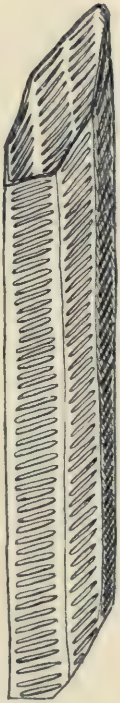


FIG. 419.

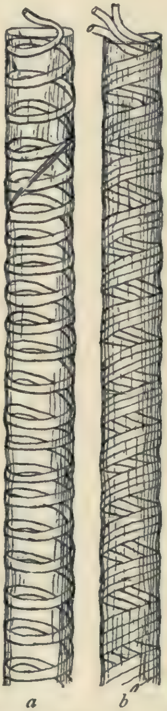


FIG. 420.

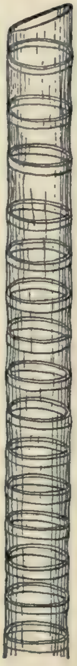


FIG. 421.

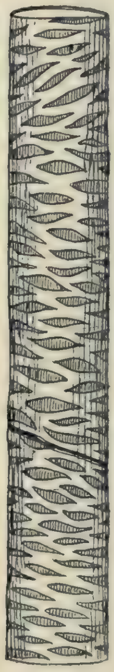


FIG. 422.

FIG. 418.—A dotted or pitted duct from Milk-weed; magnified 200 diameters.
FIG. 419.—Part of a scalariform duct from a fern; magnified 150 diameters.
FIG. 420.—Spiral ducts: *a*, one with a single spiral band; *b*, one with a triple spiral—magnified about 250 diameters.
FIG. 421.—An annular duct from house Geranium; magnified about 300 diameters.
FIG. 422.—A reticulate duct from house Geranium; magnified about 300 diameters.

(9) *Ducts or Vascular Tissues.* These, as we have seen, differ from wood tracheids, mainly in being composed of two or more cells which have become confluent end to end, forming tubes of varying length. Their diameter is commonly large, compared with that of the wood cells of the same plant, and they are usually much longer. When mature, their walls are

lignified, their lumen commonly filled with air, though sometimes with cell-sap, and they are destitute of protoplasm. The thickenings, which constitute the markings, are on the internal surface of the wall, and the different kinds of ducts are named from the character of these markings.

The following kinds are the most important :

a. The *Dotted* or pitted are characterized by rounded or oblong, thin areas or pits scattered over the wall, as in Fig. 418.

b. The *Scalariform* differs from the dotted chiefly in the fact that the pits are greatly elongated in a transverse direction, giving rise to markings which bear some resemblance to the rounds and spaces of a ladder ; hence the name ; Fig. 419.

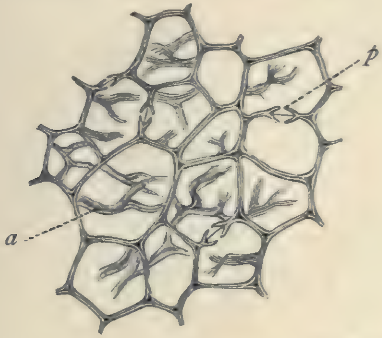


FIG. 423.

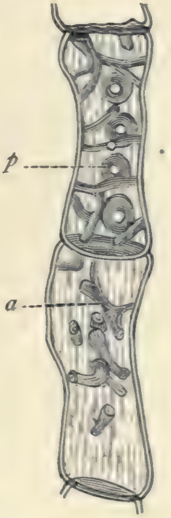


FIG. 424.

FIG. 423.—Transverse view of trabecular tracheids from leaf of common Juniper : *p*, a bordered pit ; *a*, thickening crossing the lumen of the cell. Magnified 380 diameters.
FIG. 424.—Longitudinal view of the same, magnified to the same extent. The letters also refer to the same structures.

c. The *Spiral* are those in which the markings consist of spiral thickenings. The spirals may be loosely or compactly arranged ; they may be single, double, treble, or even sextuple. The rest of the wall on which they are borne is usually thin, so thin that when a stem or other organ containing them is torn asunder by a longitudinal strain, the cell-wall is ruptured, and the spirals are drawn out sometimes to great length, and appear to the naked eye like spider lines. Two of these ducts are shown in Fig. 420, *a* and *b*.

d. The *Annular* duct is one in which the thickenings take the form of rings, Fig. 421. Transition forms between these and spiral ducts are often met with. For example, one end of the duct may possess a spiral, while the other is annulate.

e. The *Reticulate* duct is one in which the thickenings take the form of a reticulum or network, as in Fig. 422. Intermediate forms between this and the spiral are also sometimes seen, and gradations occur between this and the dotted duct.

f. The *Trabecular* duct is a rarer form, in which the thickenings cross the lumen of the cell. On either side of the central fibro-vascular bundle in the leaf of the common Juniper occur tracheids having thickenings of this character. Fig. 423 represents some of them as they appear in transverse section, and Fig. 424 some of the same in longitudinal view.

(10) *Hard Bast or Liber fibers.* These consist of greatly elongated, usually taper-pointed, but sometimes forking or sparingly branching, very thick-walled, tough and flexible cell-derivatives. Their walls, when mature, are strongly lignified, frequently unequally thickened, and often marked with delicate, oblique, slit-like markings. They are usually more highly refractive and lustrous than wood-fibers, and with saffranin stain a brighter rose-red ; they are also, in the majority of cases, relatively longer and thicker walled. Occasionally, though not commonly, transverse septa may be observed in them, as in some wood cells, dividing the narrow lumen into two or more compartments, and not uncommonly they may be observed to contain crystals of mineral matter.

Bast fibers proper constitute the tough and stringy tissues in the liber or inner bark of Dicotyledons, such as the Bass-wood. Flax and Leatherwood. The value of Flax for the production of textile fabrics depends upon the presence of these fibers. See Figs. 425 and 426.

Though bast fibers, in the strict sense of the term, are confined to the bast or phloem portion of fibro-vascular bundles, fibers structurally indistinguishable from them often occur elsewhere in the plant. Examples of these are the masses of brown fibers found in the fundamental tissues of some Ferns ; the isolated and very irregular, often branching, fibrous cells found in the parenchyma of some leaves, as those of the Tea-plant ; the fibrous tissue that surrounds and strengthens some fibro-vascular bundles, as those of Maize ; the strengthening cylinder immediately underlying and supporting the epidermis of some plants, as that of the stems of many Monocotyledons and Ferns; and the fibrous strengthening cylinder sometime found imbedded in the parenchyma of stems considerably beneath the epidermis and outside of the fibro-vascular bundles, as in the stem of the Pumpkin. The term "bast-fibers" may, therefore, be legitimately applied to all these, and in this sense is used in this work, though many authors limit the term to the fibers found in the bast, and call all lignified, fibrous elements, wherever found, *sclerenchyma fibers.* According to this usage, bast-fibers, wood-cells, wood-tracheids, etc., are only varieties of sclerenchyma fibers.

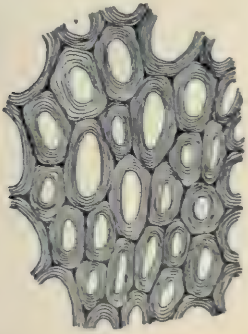


FIG. 425.

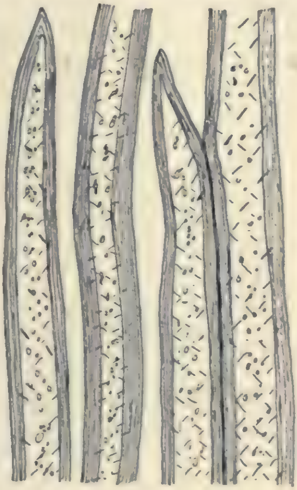


FIG. 426.

FIG. 425.—Transverse section of bast cells from the stem of Menispermum canadense. The middle lamella is shaded dark, and the walls of the thickened fibers show concentric lamination. Magnified about 400 diameters.

FIG. 426.—Longitudinal view of small portions of the long bast fibers from the stem of the same plant, showing oblique markings in the cell walls. Magnified about 400 diameters.

Associated with bast-fibers are sometimes found shorter blunt-ended cells which otherwise resemble them. These are often called *rod* or *staff cells*, and they may be regarded as intermediate in their character between bast-cells and stone-cells. In fact, every gradation may be observed between them.

III.—Sieve Series. This includes the different varieties of:

Sieve Cells or *Cribiform tissue.* This tissue is seldom formed elsewhere than in the phloem or bast-region of fibro-vascular bundles. It consists usually of elongated, thin-walled and blunt, or somewhat oblique-ended cells, which have areas with sieve-like perforations, technically called sieve-plates, on some portion of their surface. Accompanying them are elongated parenchyma cells rich in albuminoid contents, often called *companion cells.* The sieve and companion cells, with ordinary parenchymatous elements that may also be present, constitute the *soft-bast;* or, owing to the fact that in dicotyledons this region is difficult to distinguish from cambium, it is sometimes called *cambiform tissue.*

In some forms of this tissue, as in the stem of the Pumpkin, where it is abundant and well developed, the ends of the cells, and not the sides, have the most prominent sieve-plates, as in Figs. 427 and 428. In others they are more prominent on the side walls than on the end partitions, but not infrequently they occur on both, as may be seen in some of the sieve-cells of the Pumpkin. Sieve-tubes usually contain a thick, slimy, albuminous matter, that is most abundant and dense next to the transverse plates, as shown in Fig. 428, which represents a longitudinal view of sieve-tissue from the Pumpkin stem after having been treated with alcohol. In places the albuminoid matter has shrunken

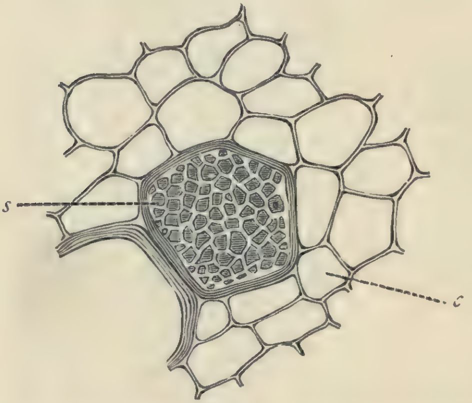


FIG. 427.

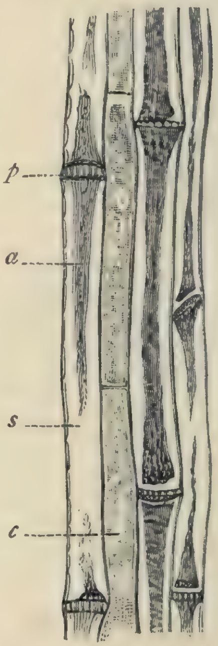


FIG. 428.

FIG. 427.—Small portion of phloëm of Pumpkin stem, in transverse section, showing sieve cells. *s*, represents one of the sieve plates; *c*, is a companion cell. Magnified about 385 diameters.

FIG. 428.—Longitudinal view of sieve tissue from Pumpkin. *s*, a sieve-cell; *p*, a thickened sieve-plate; attached to either surface of the sieve-plate are masses of albuminoid matter, *a*, shrunken by treatment with alcohol; *c* companion cell. Magnified about 150 diameters.

away from the sieve-plate. This matter is continuous from one cell to the next through the perforations in the plates; thus sieve cells, during the growing season, at least, form long, continuous tubes, through which nutritive materials circulate in the plant. The sieve-plates are usually considerably thickened, often with a deposit of a peculiar character called *callus*, but the rest of the cell-wall remains very thin, and is composed of unmodified cellulose.

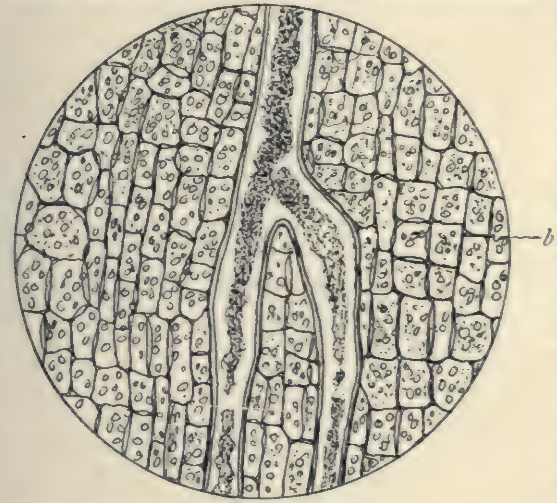


FIG. 429.

IV.—Laticiferous Series. Many plants, when wounded, emit a milky fluid, varying in color, copiousness, consistency and chemical composition in different plants. The tissue which contains the fluid, or latex, is called *laticiferous tissue*.

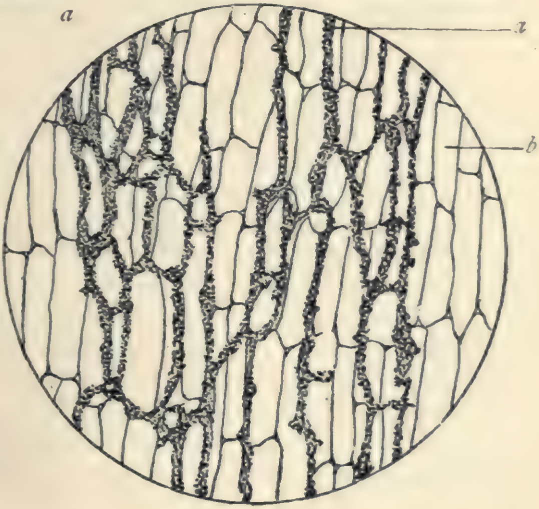


FIG. 430.

FIG. 429.—Simple laticiferous tissue from the root of Apocynum androsæmifolium. *a*, milk tube containing coagulated latex; *b*, cortical parenchyma cells. Magnified 155 diameters.

FIG. 430.—Complex laticiferous tissue from longitudinal tangential section of root of Dandelion. *a*, milk-vessel; *b*, parenchyma cell. Magnified 155 diameters.

It differs considerably in different plants, and is not confined to any particular portion of the plant, or to any tissue system, but it is most common and most abundant in the parenchyma. Two kinds are distinguished –the *simple*, in which the milk-containing tubes consist of single, greatly elongated, and usually branching cells, as in the Euphorbias and Asclepiads, Fig. 429, and the *complex*, in which they consist of coalesced cells, forming an irregular net-work of tubes, as in the Dandelion and other Cichoraceæ, Fig. 430. Closely allied, apparently, to this latter variety of laticiferous tissue, are the secretion cells of some plants, as those in the rhizome of Sanguinaria. Here we find, in fact, every gradation between isolated cells and chains of cells that have coalesced into tubes, Figs. 431 and 432.

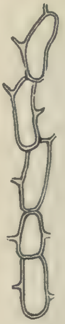


FIG.431.

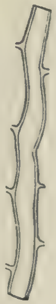


FIG.432.

FIG. 431.—Row of secretion cells from rhizome of Sanguinaria. Magnified about 75 diameters.

FIG. 432.—Portion of milk tube from the same plant, composed of several confluent secretion cells. Magnified about 75 diameters.

Secretion Receptacles. These are not to be regarded as constituting a distinct tissue, since for the most part they are but slightly modified parenchyma. It is convenient to classify them according to their contents.

Some contain crystals, and are called *crystal cells*. In many of these the protoplasmic and other contents have almost, if not completely, disappeared, and the cell is nearly or quite filled with the crystals. Though crystals are much the most abundant in parenchyma cells, they are by no means confined to them.

Other cells, on account of their resinous or balsamic contents, are called *resin cells;* others, containing mainly tannin, are called *tannin cells;* still others that are filled with volatile oil are termed *oil cells;* and those that contain an abundance of mucilaginous or gummy matter are denominated *mucilage cells.*

Primary Meristem. This term is applied to young and forming cells, such as those found in the growing season between the wood and the bark of Dicotyledons, at the growing apex of the stem, root, etc. It is not to be regarded as a separate tissue, but as made up of cells which are not yet differentiated or developed into distinct tissues. It is always thin-walled, the cells are relatively small, destitute of intercellular spaces, and in a state of active division.

RECAPITULATION OF TISSUES.

I.—*Parenchymatous Series.*

1. Parenchyma, or soft tissue.
2. Collenchyma, or thick-angled tissue.
3. Sclerotic parenchyma, or stony tissue.
4. Epidermal, or boundary tissue.
5. Endodermal Tissue.
6. Suberous, or corky tissue.

II.—*Prosenchymatous Series.*

7. Wood, or libriform tissue, also called woody fiber.
8. Tracheids, or vasiform cells.
9. Ducts, or vascular tissue, including:
    - *a.* Dotted ducts.
    - *b.* Scalariform ducts.
    - *c.* Spiral ducts.
    - *d.* Annular ducts.
    - *e.* Recticulate ducts.
    - *f.* Trabecular ducts.
10. Hard bast tissue, or liber fiber.

III.—*Sieve Series*, including only

11. Sieve, or cribriform tissue.

IV.—*Laticiferous Series*, including

12. Laticiferous, or milk tissue, of which there are two varieties: (*a*) Simple. (*b*) Complex.

Intercellular Spaces. These are cavities, sometimes minute and sometimes of considerable size, found chiefly in mature tissues. Their contents are various; sometimes they contain only air; at other times, water, crystals, milky or resinous secretions, etc.

They are formed in different ways; sometimes by the splitting of the common cell-wall which separates adjacent cells, a mode of formation described by the term *schizogenous*, and sometimes by the rupture and destruction of certain cells, a process described by the term *lysigenous*. Examples of the former are the small triangular intercellular spaces in the pith of the Elder and in parenchyma tissues generally, and the large, and comparatively regular air-spaces in the stems of the Water-plantains, Arums and Water-lilies; of the latter, the hollows in the stems of Equisetums, Grasses, Umbelliferæ, Compositæ, Labiatæ, etc.

The intercellular spaces in leaves, particularly those of land plants, are usually larger than those of the stem and root; those which, in land plants, contain air, are usually small, except the hollows of stems like the grasses, many Umbelliferæ, etc., while those of aquatics are very large and regular in form. The latter are called *air passages*, and they serve not only to render the organs which bear them buoyant, but doubtless the air which they contain is serviceable in the respiratory processes in the plant. The peculiar internal hairs called *trichoblasts*, which are often found projecting into these air passages, have already been referred to. They are shown in Fig. 433.

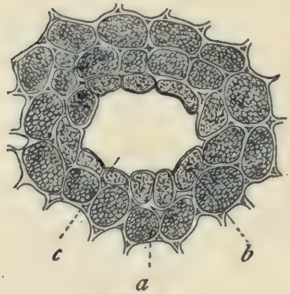


FIG. 434.

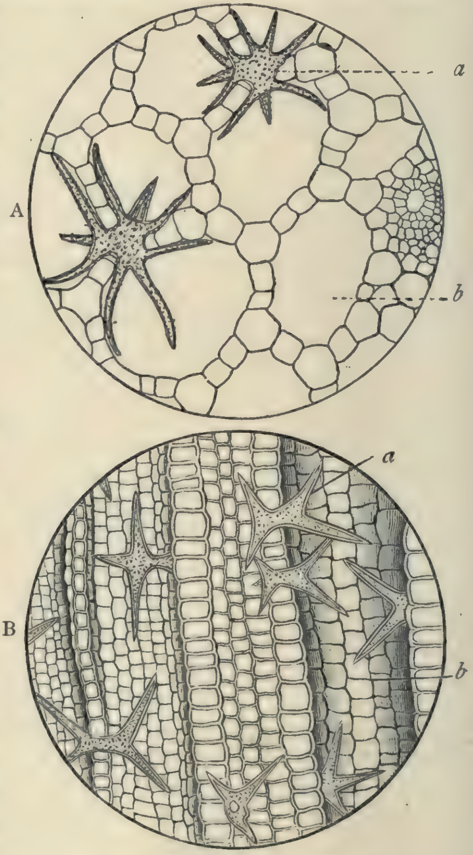


FIG. 433.

FIG. 433 (A).—Portion of transverse section of stem of Yellow Water-lily. *a*. trichoblast; *b*, intercellular air-space. Magnified about 50 diameters. (B).—Longitudinal section of stem of same plant. The letters referring to same parts as in (A). Magnified about 50 diameters. Drawing by Martin Heinemann.

FIG. 434.—Secretion reservoir from bark of rhizome of Aralia nudicaulis; *a*, starch-bearing parenchyma; *b*, secreting cells with finely granular contents; *c*, intercellular space into which the secretions are poured. Magnified about 125 diameters.

Intercellular secretion reservoirs are common in many plants, and they are also either schizogenous or lysigenous in their origin. They may form elongated and regular passages, resembling the air passages of aquatic plants, into which adjacent secretion cells pour their contents, Fig. 434, or they may be short and regular or irregular closed cavities. They may, like secretion cells, contain oleoresins, balsams, gum-resins or mucilage, and in some instances their form and contents make them liable to be confounded with laticiferous ducts.

Practical Exercises.

1. Obtain in spring or early summer, when vegetative growth is rapid, some filaments of Spirogyra; examine them microscopically by daylight, and note that the cells all appear well developed, and no signs of cell-division are observable. This is because in these plants the cell-division takes place in darkness. Let the filaments remain in water in a dark room until after midnight; then place them in 60 per cent alcohol, which will stop their growth and kill the protoplasm. Now study them microscopically, and cells will be found in all stages of division, some in which the nucleus has just divided, and an annular protuberance on the interior of the cell wall (the beginning of a cellulose septum) has made its appearance; others in which the division is nearly completed, and still others in which the separation into two cells is quite complete, but the new cells have not yet attained their full growth.

Make drawings of different stages in the process.

2. Strip off a small portion of the epidermis from the middle or basal portion of the leaf of a Lily (any one of the garden or wild lilies will answer), treat it with 60 or 70 per cent. alcohol for an hour, then stain with Grenacher's carmine or Grenacher's hæmatoxylin, permitting the tissue to remain in the staining solution for some hours, then examine it microscopically. Cells will probably be found in which the nucleus is separating into two, and others in which the division is complete, a new and very thin cell-wall being formed across the cell.

3. Examine a drop of active brewer's yeast under a magnifying power of 600 or 700 diameters. Budding cells will be observed, with the buds in various stages of development. Make drawings of some of them.

Obtain a piece of porous tile; place one end of it in a small dish containing water. The portion not immersed will be kept moist by capillary attraction. On this portion place a little yeast; cover the whole with a bell jar; keep in a moderately warm place for a few days, and then examine the yeast. Some cells will probably be found in which the protoplasm has broken up into several small, rounded masses, presenting an example of internal cell-formation.

The little red Cup-fungus, Peziza coccinea, is not uncommon in our woods. Make a thin, vertical section of the "cup" or hymenium of one of these plants, and examine with a magnifying power of 300 or 400 diameters. Numerous elongated cells, each containing a number of oval spores called ascospores, will be observed. Some of the latter may be seen escaping from the top of the asci, or mother cells. Draw one of the asci with its contained ascospores.

4. The rejuvenescence of cells may be observed by patiently studying the filaments of such fresh water algæ as Stigeoclonium, Oedogonium, and some others. This process, as it occurs in Oedogonium, is illustrated in Fig. 396, *a* and *b*.

5. For the study of conjugation, select masses of Spirogyra late in the season, when they have acquired a brownish color and a crinkled appearance, and examine them under a moderate magnifying power. Every stage in the process may often be seen in a single field of the microscope. Make drawings of the successive stages.

The same process may also be conveniently studied in Mesocarpus, another filamentous alga, and in the Diatoms and Desmids. All of these plants are abundant in our fresh waters.

6. The process of fertilization may best be studied in the Vaucherias, or Green Felts, filamentous algæ found growing in intricate, felt-like masses in the vicinity of springs, on damp rocks, or on the surface of wet, spongy soil.

The process may be studied without great difficulty in the flowering plants, as follows :

Take the pistil of Datura Stramonium (or of some other flower whose ovary, style and stigma are rather large), and, immediately after the withering of the corolla, make thin, longitudinal sections through the stigma, style and ovary. Pollen grains will ordinarily be seen attached to the stigma, and pollen tubes may be traced into the style, particularly if the section be heated for a few moments in glycerine, so as to render the cells of the style as transparent as possible.

The pollen tube may be distinguished by its more granular contents from the cells among which it has penetrated.

If the sections are fortunately made, the pollen-tube may even be traced into the micropyle of the ovule. But if this cannot be done, some of the young ovules, if removed and carefully examined, will be found to contain the ends of pollen-tubes which have penetrated the micropyle and are in contact with the nucleus of the ovule. If the ovary of almost any species of the Orchidaceæ be cut open longitudinally a short time after the corolla has withered, numerous pollen-tubes will be seen, appearing under a magnifying-glass as delicate, white, silky threads. The ovules of these plants are also favorable for the study of fertilization owing to their small size and the transparency of their parts. Other suitable plants for the purpose are the species of Pyrola, Monotropa, and Torenia Asiatica.

7. For the study of the different kinds of vegetable tissues, make, first, thin longitudinal and transverse sections of the stem of the house Geranium. The large pith, and most of the tissues outside of the fibro-vascular ring, are composed of ordinary parenchyma cells, which may be studied without any preparation of the sections further than mounting them in water. Make careful studies and drawings of a few of them as they appear in both sections.

Study the epidermal cells, together with the glandular and other hairs attached to it, in the same way.

Now treat the longitudinal section for a few moments with hot Schulze's maceration fluid ; rinse it in water ; put it on a glass slip ; cover it with a cover-glass; gently tap the latter with a needle-point, so as to jar the cells apart, and study the prosenchyma tissues.

Wood-cells, tracheids, bast-cells and spiral, annular and reticulate ducts may readily be distinguished. More satisfactory results will be obtained if, after treating the section with Schulze's maceration fluid and washing, it be stained with an aqueous solution of methyl-green. The liquified tissues will then be more strongly stained than the rest and their structure more readily recognized. Make drawings of each of the tissues.

With a very sharp plane, make of White Pine wood thin cross-sections, thin longitudinal sections parallel with the rings of growth, and thin longitudinal sections at right angles to the rings of growth, and study the discigerous tracheids. Make drawings of them as they appear in the different sections.

With a sharp knife, make some thin sections of the shell of a Hickory nut, some of them parallel with the surface, and others at right angles to it; treat the sections with hot Schulze's maceration fluid; rinse, stain with methyl-green, mount in water, and jar the cells apart by tapping the cover-glass with a needle; then study the cells with a magnifying power of 300 or 400 diameters. Observe the excessively thickened walls, and the concentric and radial markings, and make drawings illustrating the shape and structure of the cells.

Make transverse and longitudinal sections of the stem of the Yellow Dock, Rumex crispus, and examine them for collenchyma tissue. In the transverse section this will be observed in masses in the obtuse angles just beneath the epidermis. It should be studied under a magnifying power of 400 or 500 diameters. Draw a portion of the tissue as it appears in both sections.

Excellent examples of this tissue are also found in the petioles of the Pie-plant, Begonia, and Grape.

Beautiful examples of scalariform ducts may be isolated for study by treating longitudinal sections of the underground stem of the Common Brake, Pteris aquilina, with Schulze's Maceration fluid, and fine examples of dotted ducts may be found in many common woods, as the Maple, Walnut, Oak, Butternut, etc. Trabecular tracheids may be found in the leaves of the common Juniper.

For the study of sieve-tissue, transverse and longitudinal sections of the stem of the Pumpkin may be made. In the transverse section they appear as rather large cells in the outer and inner portions of the radially elongated fibro-vascular bundles. The longitudinal sections are best studied by treating them first with alcohol, to kill the protoplasm, and then, after rinsing in water, staining them with eosin. The proteid contents of the sieve-tubes will then be shrunken and stained bright red, so that the tubes may readily be traced. This treatment is not advantageous for the cross-section, as the staining of the albuminoid matters in the cells obscures the sieve-plates. The latter may be rendered beautifully distinct by soaking the section in a solution of soda-corallin. This serves well also for the study of the longitudinal section. Draw one or two of the sieve-tubes. They may also easily be studied in the petiole of the Grape.

Simple laticiferous tissue may be studied in the stem of Euphorbia splendens, or in that of other species of Euphorbia. The stem should, immediately after removing it from the plant, be placed in strong alcohol, to coagulate the latex and prevent its escape from the vessels. Sections should then be made longitudinally through the bark. The long, somewhat branching cells may be traced by means of their granular, dark-colored contents, the coagulated latex. The vessels may usually be more satisfactorily traced by dipping the section for a few moments in nitric acid, rinsing well in water and then staining in an aqueous solution of methyl-green.

Complex laticiferous tissue may be studied by making similar longitudinal sections of Dandelion or Chicory Roots. Similar precautions should be observed to prevent the escape of the latex from the vessels. Study, also, the distribution of the tissue as it appears in a cross-section of the root.

Make drawings of both kinds of laticiferous tissues.

Make transverse and longitudinal sections of the stems or petioles of the Bulrush, Yellow Water-lily or Pickerel-weed, and make studies and drawings of the large intercellular air-spaces. Note, also, the trichoblasts, found abundantly in the Yellow Water-lily.

For the study of secretion reservoirs, sections of the rhizome of Aralia nudicaulis of the root of Aralia racemosa, of the stem of any Umbelliferous plant, or of the twigs of Pines or Firs, may be made. They may easily be recognized from the descriptions already given.

CHAPTER III.—TISSUE SYSTEMS.- ORGANS OF PLANTS.

The tissues of plants are not scattered without order through the vegetable structure, but are grouped into systems. Usually three tissue-systems are recognized, the *epidermal*, the *fibro-vascular*, and the *fundamental.*

1.—The Epidermal System. This includes the epidermis and its various appendages, stomata, water-pores, hairs and glands already described. Its function is chiefly protective, and particularly to protect the plant against the excessive evaporation of water from its interior tissues. To this function the compact arrangement of the cells and the cutinization of their walls admirably adapt them.

2.—The Fibro-Vascular System. This constitutes the fibrous frame-work of the plant. In the leaf, it is the system of veins, and in the stem and root the tough and resistant portion. Its function is partly to give strength to the organs of which it forms a constituent part, and partly to conduct the fluids of the plant from one part to another.

The cells composing it, therefore, for the most part, have thickened walls, and they are elongated in the direction of the length of the organ which bears them. They belong to the prosenchymatous series chiefly, although other tissues are commonly included.

In some plants, as in the stem of Indian Corn and the petioles of the Plantain, the fibro-vascular bundles may be readily separated in the form of tough, stringy masses from the softer surrounding tissues.

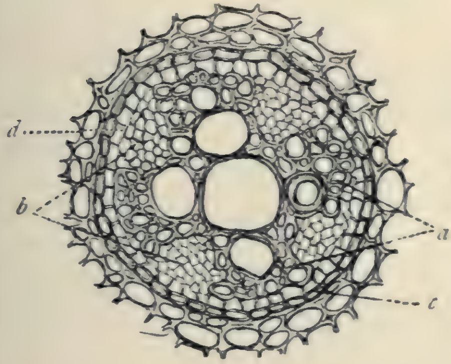


FIG. 435.

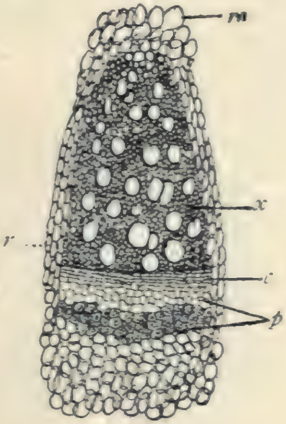


FIG. 436.

FIG. 435.—Radial fibro-vascular bundle from root of Buttercup. *a*, two of the four xylem rays; *b*, two of the four phloem masses; *c*, endodermis or bundle-sheath; *d*, pericambium. Magnified about 100 diameters. After De Bary.

FIG. 436.—Diagram of open collateral bundle. *x*, xylem, mainly composed of ducts and wood cells; *p*. the phloëm, containing bast-fibers and sieve-cells; *c*. cambium layer, composed of small, thin-walled and imperfectly developed cells; *r*, medullary ray; *m*, portion of medulla or pith.

Although most of the different kinds of tissues described in the last chapter may be found in a fibro-vascular bundle, only two of them are really essential, ducts (or tracheids, which may be regarded as imperfectly formed ducts) and sieve-cells. These and their associated tissues always constitute separate longitudinal portions of the bundle. The portion to which the ducts belong is called the *xylem*, and that to which the sieve-cells belong, the *phloem*. Sometimes the bundle is sharply marked off from the surrounding tissues by a *sheath*, or *endodermis*, composed of a single row of cells different both from those exterior and from those interior to it, Fig. 435, *c*. In many cases, however, no endodermis is present. Outside of the endodermis and immediately in contact with it there may also be one or more thicknesses of thick-walled cells, often fibrous in their character, constituting a strengthening layer.

According to the relative arrangement of the xylem and phloem masses, three kinds of fibro-vascular bundles are distinguished, the *collateral*, the *concentric*, and the *radial.*

(*a*) *The Collateral Bundle* is characterized by having the xylem and phloem masses arranged side by side, and usually in such a manner that the former faces interiorly, and the latter exteriorly, as regards the organ that bears it. In leaves, the xylem faces the upper or ventral surface, while the phloem faces the lower or dorsal surface. In Fig. 436, *p* is the phloem, and *x* the xylem. Bundles of this kind are characteristic of the stems and foliage leaves of nearly all flowering-plants, but they seldom occur in roots.

Two varieties are distinguished, the ordinary form, in which there is one mass each of xylem and phloem, and the *bi-collateral* bundle, in which there is one mass of xylem between two of phloem. The latter variety is found only in the stems of members of the gourd family, and in a few other plants.

Some collateral bundles continue to increase in thickness during the life of the organ which contains them, and the growing layer is located at the junction of the xylem with the phloem. Such bundles are called *open* bundles, while those which soon cease to grow or form new tissues are called *closed* bundles. The former are characteristic of the stems of woody Dicotyledons. In this case, the bundles are radially arranged with the phloem masses pointing outward, and the growing layer is continued across from bundle to bundle, constituting a continuous zone, which forms the line of junction of the wood with the bark. This is called the *cambium zone.* The cambium of a bundle is shown in Fig. 436, *c.* The bundles found in the stems of most Monocotyledons are of the closed collateral variety.

(*b*) *The Concentric Bundle.* This differs from the last in having one of the two elements of the bundle (xylem or phloem) placed centrally and surrounded by the other. In the concentric bundles of most Ferns and Club-mosses the xylem tissues are surrounded by phloem, while in the outer series of fibro-vascular bundles found in the rhizomes of some Monocotyledons, the reverse order prevails,—that is, the xylem surrounds the phloem. Fig. 437 represents the concentric bundle of Pteris aquilina, a Fern. The large scalariform ducts occupy the interior of the bundle; the sieve and other phloem tissues are exterior to these, and the whole is surrounded by the endodermis.

(*c*) *The Radial Bundle.* In this form of bundle the xylem tissues are arranged in radial bands or plates, and each is separated from the next one by a mass of phloem tissues. In Fig. 435 there are four radiating masses of xylem alternating with as many of phloem. The whole is surrounded by a bundle-sheath consisting of rather thick-walled cells. Sometimes the bands of xylem meet in the centre, and in other cases they are connected by a central cylinder of parenchyma, forming a kind of pith. Radial bundles occur in most roots, and in the filiform stolons of Nephrolepis, a Fern. In the section of the fibro-vascular bundle of the root of Acorus Calamus, represented in Fig. 438, which may be taken as typical of the kind, the whole bundle is seen to be surrounded by an *endodermis;* interior to this is a layer of active, thin-walled cells, called the *pericambium*, from which new roots originate; plates of tracheary tissue farther interior alter-

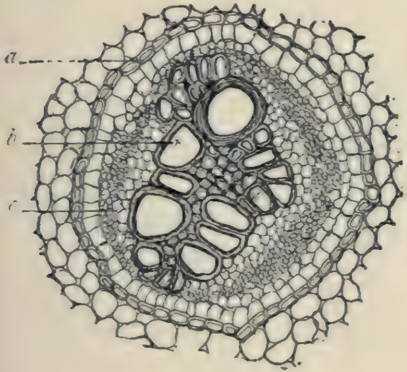


FIG. 437.

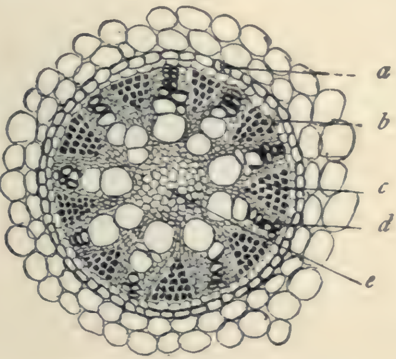


FIG. 438.

FIG. 437.—Concentric fibro-vascular bundle of Pteris aquilina: *a*, endodermis; *b*, large scalariform duct in xylem; *c*, phloem tissues surrounding the xylem. Magnified about 150 diameters.

FIG. 438.—Radial fibro-vascular bundle from the root of Acorus Calamus; *a*, endodermis; *b*, pericambium; *c*, phloem mass; *d*, xylem ray, composed mainly of ducts, the outer ones of which are thick-walled, and the inner ones larger, but thinner walled; *e*, central parenchyma. Magnified about 125 diameters. After DeBary.

nate with masses of sieve tissue; these alternating masses are not in contact, but separated from each other by thin plates of parenchyma; and in the centre of the bundle is an area usually consisting of parenchyma, and then constituting a kind of false pith, but sometimes it is filled with xylem tissues to the centre, as in the root of Tradescantia Virginica.

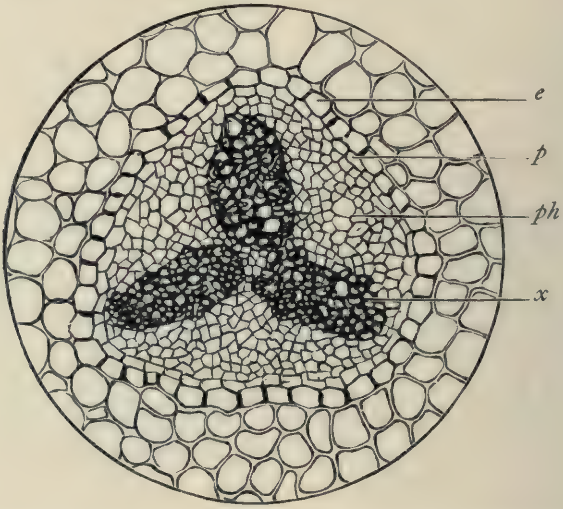


FIG. 439.

FIG. 439.—Radial bundle from root of Botrychium Virginicum. The bundle is triarch or three-rayed. *e* is the endodermis; *p*, the pericambium; *ph*, a phloem mass; and *x*, a strongly lignified xylem ray.

Imperfect or rudimentary fibro-vascular bundles are of common occurrence. In the ramifications of leaf-veins, for example, the elements of the bundle disappear one by one, until, in the finer branches, but a single element, say a spiral vessel or tracheid, may be left, and in many herbaceous plants, particularly aquatics, the bundles are greatly depauperated, so that even the ducts are often wanting.

The Fundamental System. This is the system of tissues through which the fibro-vascular bundles are distributed. It includes all the tissues of the plant except those which are included in the fibro-vascular and epidermal systems.

In the lower forms of plant life it usually forms a very large portion of the plant structure, and this is true, also, of the herbaceous forms of the higher plants. In woody plants its proportion is much smaller; but in all plants it contains tissues of great importance to the life of the plant. To this belong the parenchyma or pulp of leaves, the cells of the medullary rays, pith, and exterior layers of the bark in the stems of Dicotyledons, and most of the soft cellular tissue in all plants.

Besides parenchyma, it may include collenchyma, cork, sclerotic, laticiferous, and sometimes even fibrous tissues. The region of fundamental tissue just beneath the epidermis, often consisting of collenchyma, sclerotic or fibrous tissue, and therefore usually firmer than the interior tissues of this system, is frequently called the *hypoderma*.

HISTOLOGY OF THE ORGANS OF PLANTS.

In the same manner that tissues are grouped into systems, so, also, the latter are grouped to form the organs of the plant. These, as has already been seen, consist of roots, stems, leaves and plant-hairs, together with their various modifications. Occasionally an organ is so simple as to be composed of but one kind of tissue, as the leaves of many mosses and the great majority of plant-hairs, but usually they are complicated structures.

Histology of the Root. The general structure of a root may be best understood by reference to an illustration. Fig. 440 represents a thin longitudinal section of the tip of a root of Buckwheat: *a* is the growing point; *bb*, the root-cap; *cc*, the epidermis imperfectly developed; *dd*, the partially formed cortex or bark; and *e*, the imperfectly developed central cylinder. Counting the root-cap as belonging to the epidermis, there are thus three layers of cells, and this is the usual number, although in a few cases four are distinguished, and in some cases but two.

The Root-Cap.—This is formed of parenchyma cells, which increase in number at the growing point, hence the older cells are nearer the surface of the root and the whole forms a kind of cap, which covers and protects the growing apex.

In most roots the cap is inconspicuous, but in some aquatics like the Duck-weed, Fig. 28, Part I, it is well developed. In many aerial roots it is no less conspicuous, and is also composed of firm-walled cells. This is the case with the roots of many of the epiphytic Orchids.

The Epidermis.—This may be present, or it may be early replaced by the growth of the sublying tissue of the cortex, particularly by the formation of cork cells.

When present, the tissue is substantially the same as that already described under epidermal tissue. Stomata, however, are never present.

Root Hairs.—Beginning a short distance above the root-cap, and extending a little way up the rootlet, the epidermis, or the superficial layer of the cortex which replaces it, is densely covered with root-hairs. The character and function of these hairs have already been described. As the root lengthens, the old hairs above wither and disappear, while new ones are continually formed below.

The Cortex.—This varies greatly in different plants. It may be thick or thin; it may be made up almost wholly of parenchyma, or it may contain a variety of tissues, such as collenchyma, sclerenchyma, cork, fibrous tissue, secretion cells, and laticiferous ducts.

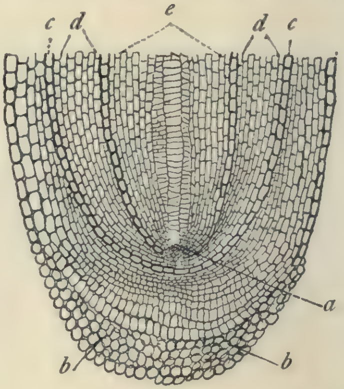


FIG. 440.—Diagram of root-tip as it appears in longitudinal section, illustrating the different regions. *a*, the growing point; *b b*, the root-cap; *cc*, imperfectly developed epidermis; *d d*, imperfectly developed primary cortex; *e*, imperfectly formed central cylinder. Much magnified.

It is usually, however, less complex in its structure than the cortex of the stem. The inner layer of the cortex constitutes the *endodermis*, which ensheaths the central cylinder.

The Central Cylinder.—This, in the root of Club-mosses, Ferns and nearly all flowering-plants, consists at first of a radial fibrovascular bundle, Figs. 438 and 439.

The number of radiating masses of xylem and phloem, in the central cylinder, varies greatly in different plants. In the Cruciferæ there are usually two of each; in the root of the Castor-oil plant, four; in that of the Bean, five; in that of the Beech, eight; in that of Amaryllis, about twenty-one; and in that of Indian Corn as many as fifty. In general, the rays in the roots of dicotyledons are few, while in monocotyledons they are usually numerous.

Secondary Changes in Roots. Many roots, as those of most Monocotyledons and vascular cryptogams, undergo little change, except increase in size and the cutinization or lignification of certain tissues in the course of their development; while others, as those of most Dicotyledons, may undergo very considerable changes, either in the cortex, in the central cylinder, or in both.

In Gymnosperms, and some Dicotyledons, the primary cortex disappears, and is replaced, largely, at least, by cork derived from the pericambial layer; in the roots of many other plants the primary cortex persists, and cork is developed in its outer layers, while new parenchyma is formed in the inner layers.

The most important secondary changes, however, are those which pertain to the central cylinder of the roots of Dicotyledons and Gymnosperms. They consist in the formation of new wood and liber by means of a cambium zone which, in appearance, resembles that in the stems of the same plants, but which is really of a different origin.

It originates in the following manner: Behind or interior to each phloem mass of the radial bundle that constitues the central cylinder, cells begin to divide. These cells constitute an uninterrupted zone of meristem or cambium tissue. By its growth the original phloem masses are carried outward, and form an interrupted zone exterior to the xylem, while the outer cells of the cambium develop into new phloem, and the inner ones into xylem. In such roots, therefore, as in the stems of the same plants, the phloem is exterior and the xylem interior, and these are separated from each other by cambium. They also develop medullary rays, and frequently rings of growth, but, except near where the root joins the stem, they seldom possess a pith. Fig. 441 represents the two-rayed or diarch bundle of the young root of the common Beet; *a* is endodermis; *b*, one of the phloem masses; *c*, cambium cells in the act of fission; *d*, a duct of the xylem.

In some other cases, as, for example, in the roots of the Pine, the pericambium that bounds the primary bundle becomes a true cambium zone, and gives origin to new wood and new liber.

The roots of vascular cryptogams, except Lycopodiaceæ, differ from those of flowering-plants in the fact that they increase in length by the division of a single sub-apical cell instead of a mass of such cells. The roots of Lycopodiaceæ differ from those of Ferns and flowering-plants in the fact that their mode of branching is dichotomous. In the higher plants and in Ferns root-branches always originate as lateral outgrowths.

Besides the differences already mentioned between the roots of Monocotyledons and those of Dicotyledons, another may be noted, namely: the endodermis in Dicotyledons very seldom becomes thick-walled, while the reverse is commonly true of Monocotyledons.

The tissues of roots are usually somewhat less complex than those of the stems of the same plants.

It was seen in Part I that roots usually branch irregularly, while stems branch regularly. The branches also differ from those of stems as regards their origin. While those of stems originate *exogenously*, or from superficial tissues, those of roots are formed *endogenously*, or from sublying tissues. They ordinarily spring from the pericambium layer, just in front of a xylem ray of the primary bundle.

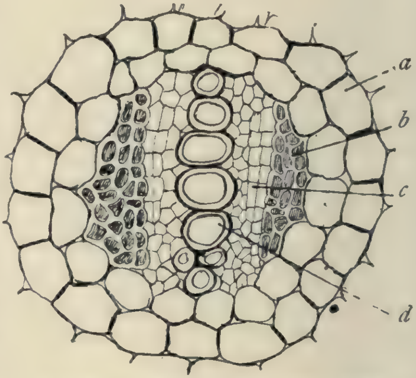


FIG. 441.—Bi-radial fibro-vascular bundle of the young root of the common Beet. *a*, endodermis; *b*, one of the phloem masses; *c*, cambium cells in the act of fission; *d*, a duct of the xylem. Magnified about 200 diameters. After Van Tieghem.

Plants below vascular cryptogams do not possess true roots, but many of them produce outgrowths of much simpler structure, destitute of vascular tissues, which serve the purpose of securing the plants to the soil or rocks. Such organs are called *rhizoids*.

Histology of the Stem. A thin, vertical section through the end of a very young stem shows much the same arrangement of tissues as is seen in the root, save that the growing point is at the apex instead of just back of it, consequently no covering of older cells analogous to a root-cap is present.

The *epidermis* presents no marked differences from that of the root, save that it commonly possesses stomata. In woody stems it is usually soon ruptured and destroyed by the growth of the sublying tissues of the cortex, but in herbaceous stems it commonly persists during the life of the organ.

The *primary cortex* usually consists of chlorophyll-bearing and other parenchyma, but it may also contain collenchyma, sclerotic, fibrous, laticiferous and other tissues, as well as secretion reservoirs. Frequently the outer portion becomes developed into a hypoderma, consisting of collenchyma, sclerotic or fibrous tissues.

The *central cylinder* soon develops in its interior one or more fibro-vascular bundles. The character of the stem and its mode of growth will depend very largely on the character and arrangement of these primary bundles.

In the lowest plants that show a clear differentiation between stem and leaf, the structure of the stem is very simple. In the stems of mosses, for example, no fibro-vascular bundles, properly so-called, are found, but in many instances the interior tissues of the stem consist of considerably elongated cells forming a mass of conducting tissue which may be regarded as anticipating the fibro-vascular bundles of higher plants.

Among vascular plants, three principal types of stem-structure may be distinguished: the *Fern type*, the *Palm* or *Monocotyledon type*, and the *Dicotyledon type*. Within the limits of each type considerable variations occur. There are also exceptional forms of rare occurrence that it would be difficult to include in any of these types.

THE FERN TYPE. This is the one prevalent in the Ferns and their allies, in which the bundles are usually of the concentric kind, consisting of xylem surrounded by phloem. Occasionally, however, they are of the radial variety. In some cases there may occur within the central cylinder but a single bundle, from which branches are given off to the leaves; in others, there may be two or more bundles placed side by side; and in still others, and this is the commonest arrangement, they are disposed in a single circle. But when distributed circularly, they are never radially elongated, as are the bundles in the stems of Dicotyledons, and if viewed in transverse section they appear either circular, or more or less lengthened in a tangential direction. Interior to the primary circle, the tissue usually consists of parenchyma, which also separates the bundles laterally, but sometimes it contains clusters of stone-cells, masses of sclerenchyma fibers, or even other fibro-vascular bundles, as in the rhizome of Pteris aquilina, Fig. 442. The cortex also usually consists mainly of parenchyma, passing toward the exterior into a thick-walled hypoderma. The type is well illustrated in the rhizome of Aspidium Filix mas. Here the principal bundles, which are from eight to twelve in number, are circularly arranged about a central parenchymatous area which contains no bundles. Each bundle of the circle sends thick anastomosing branches to those adjacent to it, so that as a whole they form a netted cylinder. From these, numerous smaller bundles pass outward through the cortex to supply the leaves (Figs. 443 and 444).

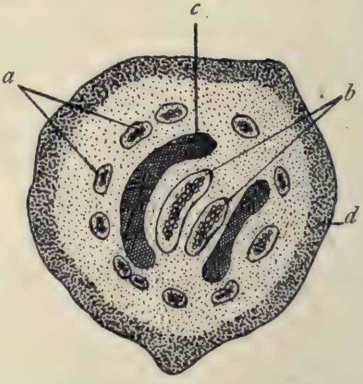


FIG. 442.—Diagram of cross-section of rhizome of Pteris aquilina, showing arrangement of tissues; *a*, two of the primary circle of fibro-vascular bundles; *b*, two large central bundles; *c*, one of the two dark-colored masses of sclerenchyma fibers; *d*, hypodermal tissue.

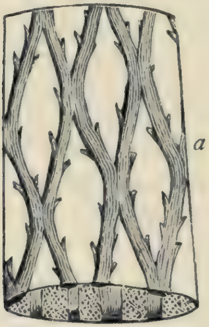


FIG. 443.

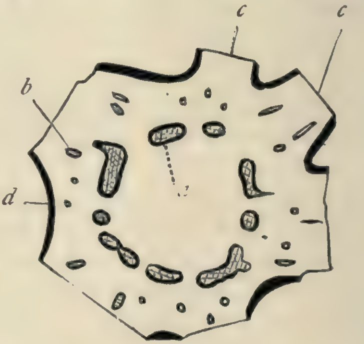


FIG. 444.

FIG. 443.—Longitudinal view of the rhizome of Aspidium filix mas with the cortical portions cut away to show the cylinder of anastomosing bundles; *a*, one of the branches of a bundle passing off to a leaf. Magnified about five diameters. Somewhat diagramatic.

FIG. 444.—Transverse section of rhizome of Aspidium Filix mas, showing arrangement of bundles; *a*, one of the bundles of the primary circle; *b*, one of the branches passing off to a leaf; *c*, *c*, places where leaves have been cut away; *d*, thick-walled hypodermal cells. The unshaded portion is mainly parenchyma. Magnified about five diameters.

In the stems of a few Ferns there is more than one circle of fibro-vascular bundles. In the stems of Lycopodiums and Selaginellas there may be a single bundle, and this may be either concentric or radial, or there may be two or more concentric bundles placed side by side, as in Fig. 445. In the stems of Equisetums, a transverse section of the internode shows a single circle of poorly developed collateral bundles surrounding a central hollow and enclosed by a common endodermis. Within each bundle at the inner side is an intercellular space, produced by the breaking down of the earlier formed xylem elements. A longitudinal section shows that the bundles run parallel in the internodes, but anastomose at the nodes where the bundles are received from the leaves.

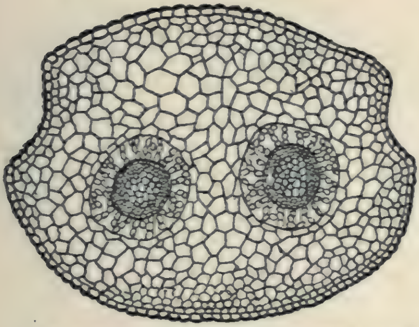


FIG. 445.—Transverse section of stem of Selaginella denticulata, showing two concentric fibro-vascular bundles side by side. Magnified about 65 diameters.

THE PALM OR MONOCOTYLEDON TYPE is the prevalent one in the sub-class of flowering plants called Monocotyledons. Here the fibro-vascular bundles are usually of the collateral type, and of that variety of it which, when mature, possesses no meristem tissue between xylem and phlœm. They are, therefore, closed bundles. As viewed in a cross-section of the stem they do not show a circular arrangement, but are scattered with little or no apparent order through the fundamental system of tissues. The phloem part of each bundle usually faces radially outward or toward the periphery of the stem, and the xylem inward or toward the centre. The bundles of the stem are all continuous with those of the leaves. From them they pass obliquely downward, or sometimes nearly horizontally inward, in a radial direction, toward the centre of the stem; thence they bend in a downward direction, and then, in a long curve, sweep gradually outward toward the circumference of the central cylinder, where they finally terminate, after coalescing with other bundles which originate from leaves higher up. The bundles do not all penetrate the cylinder to the same depth, some bend downward soon after entering it, others pass nearly or quite to its centre. Hence the irregular arrangement observed in cross-section. It is evident also that the bundles will be more numerous and crowded toward the periphery of the cylinder. The fact that stems of this type are denser exteriorly than they are in the centre, is thus, in part at least, accounted for. In some plants the central portion of the cylinder is destitute of bundles, and the thin-walled parenchyma of this region may even disappear at an early stage in the development of the stem, leaving a hollow, as in the stems of most Grasses. The bundles attain their best development in the middle portion of their course. In their progress downward and outward they become thinner and less vascular; hence, in viewing a cross-section of a stem of this kind, the best developed bundles are found to be those farthest interior, while the more imperfect ones are the ones crowded together toward the outside of the cylinder. The main points of structure in stems of this type are illustrated in Figs. 446 to 448, inclusive.

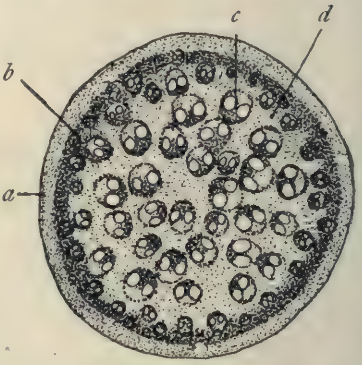


FIG. 446. Transverse section of a rather young stem of Smilax glauca, showing arrangement of fibro-vascular bundles. *a*, primary cortex; *b*, crowded and depauperate bundles, forming nearly a ring at the circumference of the central cylinder; *c*, one of the interior bundles; *d*, ground-tissue. Magnified 13 diameters.

Since the fibro-vascular bundles are closed, that is, do not possess a meristem layer, no considerable increase in the thickness of the stem can take place except by the formation of new bundles. Accordingly, the majority of stems of this type do not increase in thickness except when quite young. This is true even when they live on from year to year; the stem of a Palm, for example, having the same diameter when two feet high that it has after reaching the height of one hundred feet. The growing area of the stem is confined to the apex or its immediate vicinity, and does not extend downward as a meristem cylinder between wood and bark, as it does in the stems of Gymnosperms and Dicotyledons. In fact, in Monocotyledons no true bark is found, nor is there a true pith, nor medullary rays, nor rings of growth.

There are some exceptional Monocotyledons, however, like the Yuccas and Dracænas, whose stems do increase in diameter from year to year by means of a meristem zone in the thick primary cortex. In this layer new fibro-vascular bundles are formed resembling those first formed in the central cylinder of these and other Monocotyledons. This mode of growth will be understood by reference to Fig. 449.

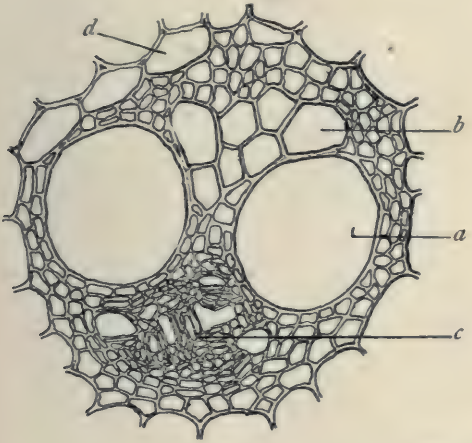


FIG. 447.

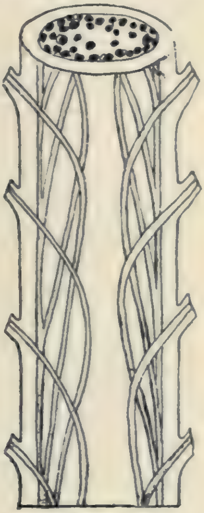


FIG. 448.

FIG. 447.—One of the fibro-vascular bundles of Smilax glauca, enlarged to 155 diameters. *a*, one of the two large ducts in the xylem; *b*, a smaller duct; *c*, phloem tissues; *d*, one of the parenchyma cells of the ground tissues.

FIG. 448.—Diagram showing course of bundles longitudinally in Monocotyledon type of stem.

It should also be observed that there are a few anomylous Monocotyledons that have their fibro-vascular bundles arranged in a manner quite different from that which has been described. In the common Yam and a few other plants the above-ground stems have the bundles arranged in a circle about a central pith, as in most Dicotyledons and Gymnosperms; and in some instances, as in Ruppia and its allies and in some Potomogetons, there is a single axile bundle which sends out branches to the leaves.

THE DICOTYLEDON TYPE. Here the course of the bundles from the leaves is inward and usually obliquely downward, and, having entered the central cylinder, their course lies directly downward, keeping at about the same distance from the centre of the stem. A cross-section of the stem, therefore, shows a circular arrangement of the bundles as in the Fern type, but the bundles are of the collateral and not of the concentric variety. They are usually shaped like a wedge, and radiate from a central portion of the fundamental tissue called the *medulla* or pith, toward which each presents its thinner edge. Separating the bundles laterally, and connecting the pith with the primary cortex are plates of fundamental tissue called *medullary rays*. The inner or thinner portion of each wedge-shaped bundle is composed of xylem, and the outer or broader portion of phloem tissues, and these are ordinarily separated from each other by a tangential layer of meristem tissue called the *fascicular cambium*. This is usually continued from one bundle to the next across the intervening medullary ray, and is here called the *interfascicular cambium*. The cambium thus forms, in most cases, a narrow zone, separating the phloem and exterior tissues, which constitute the bark, from the xylem and interior tissues, which constitute the woody region of the stem. The facts will be understood by reference to Figs. 450 and 451 and their accompanying descriptions.

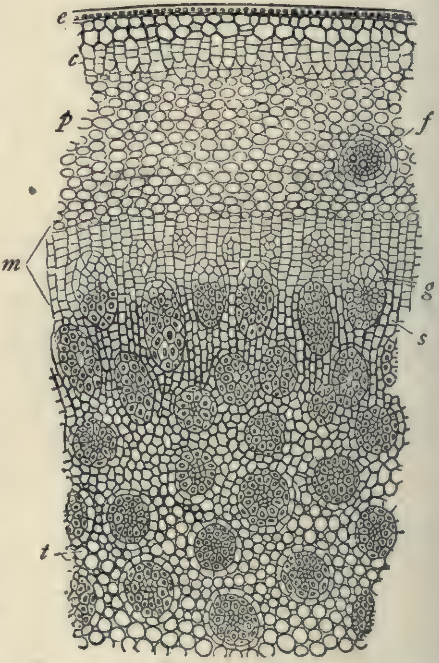


FIG. 449.—Part of transverse section of stem of Dracæna (reflexa?), showing its mode of increasing in thickness. *e*, epidermis; *c*, corky layer; *p*, cortical parenchyma; *f*, a fibro-vascular bundle passing outward to a leaf; *m*, meristem layer, in which fibro-vascular bundles are forming; *g*, a partly formed bundle, the upper or outer part of which still consists of thin-walled cells; *s*, secondary fundamental tissue, with radially arranged cells; *t*, primary fundamental tissue. Magnified about 40 diameters After Sachs.

In woody stems of this kind, every year during the season of growth, and for a time even in herbaceous stems, the cells of the cambium-layer divide by fission in a tangential direction, and those interior and next the wood are developed into xylem, and so add to the thickness of the woody region, while those exterior are developed into phloem elements, and increase the thickness of the liber. The newest wood, therefore, is its outermost layer, while the newest bark is its innermost layer.

The interior and older xylem tissues of woody stems commonly become strongly lignified and con-

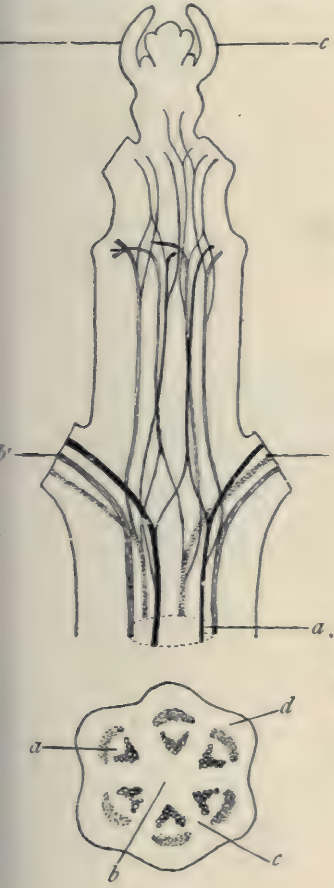


FIG. 450.

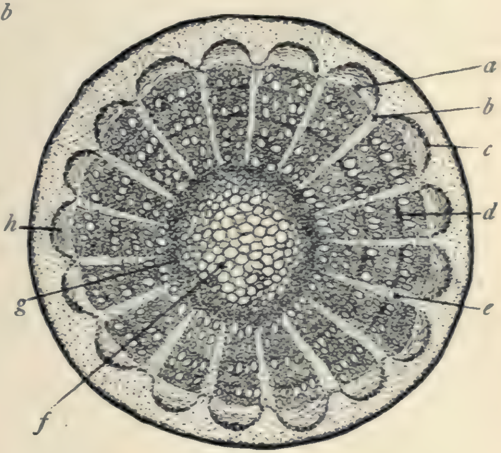


FIG. 451.

FIG. 450, A and B.—Diagrams of fibro-vascular system of stem of Clematis vitalba, a Dicotyledon.

A. Longitudinal view of upper part of stem, rendered transparent to show course of bundles. *a*, central cylinder, showing six fibro-vascular bundles arranged in a circle at its periphery: *b b'*, bundles passing off to leaves; *c c'*, rudimentary leaves near apex of stem.

B. Transverse section of young internode. *a*, a bundle with an outer, phloem part, an inner, xylem part and an intervening meristem area; *b*, pith; *c*, medullary ray; *d*, primary cortex. Both reduced from figures by DeBary.

FIG. 451.—Transverse section of a stem of Menispermum Canadense, in the third year of its growth. *a*. fascicular cambium; *b*, interfascicular cambium; *c*, a crescentic mass of bast fibers in the outer phloem; *d*, a ring of growth; *e*, a medullary ray; *f*, pith; *g*, the so-called medullary sheath; *h*, collapsed cells of the soft bast in the phloem. Magnification 14 diameters.

spicuously different in color from the rest, owing to infiltrated coloring matter. This portion of the wood, which has ceased to take any important part in the vital processes of the plant, is called *duramen*, or heart-wood, while the exterior zone of thinner-walled, uncolored and active cells is called *alburnum*, or sap-wood.

Rings of growth are observed in the wood of trees that inhabit climates where there is a decided change of seasons, so as to produce periodical cessation of growth.

These rings are formed by the juxtaposition of the small cells formed in the latter part of the season of growth, to the larger ones formed at the beginning of the succeeding season. This will be understood by reference to Fig. 452. In climates where there is during the year one period of growth and one of rest, there will usually be formed one ring each year, and the number of rings in the wood, therefore, becomes an index, approximately, at least, of the age of the stems. Sometimes, however, rings are due to other causes. Periods of drouth in midsummer, accidental losses of large branches possessing a great amount of leaf-surface, or other causes seriously interfering with regular growth, may result in the formation of two or more rings during a season. They must not be relied on, therefore, as indicating with absolute accuracy the age of trees.

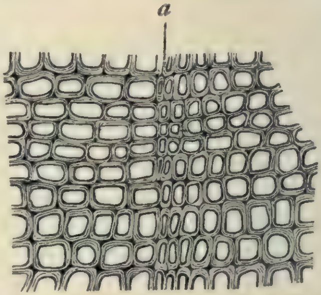


FIG. 452.—Small portion of transverse section of wood of White Pine, showing part of a ring of growth, *a*. The small cells at *a* were produced near the close of the season's growth, and the large cells immediately to the left were produced in the spring of the succeeding season.

The bark, also, in its inner layer, frequently exhibits rings of growth due to similar causes. The bark of Dicotyledons and Gymnosperms, when all the parts are present, consists of four layers, the *epidermis*, the *epiphlœum* or corky layer, the *mesophlœum* or green layer, and the *endophlœum* or liber.

The epidermis has already been described. In perennial stems it seldom persists for more than two or three years. When it first reaches maturity it forms, except where the stomata occur, a continuous covering, though minute elevations may be discernible here and there on the surface, even before the close of the first year's growth. This is due to the growth of cells at certain points beneath. During the second year, the continuity is ruptured by fissuring at these points, and the cells from beneath protrude, giving to the surface a freckled or spotted appearance. These spots are technically called *lenticels*, and their character will be understood by reference to Fig. 453.

Sooner or later, however, a corky layer or *periderm* is formed by the division of cells in a tangential direction. This periderm may be formed superficially either by the division of the cells of the epidermis itself, as in the Willow, Apple and Oleander, or, as is more commonly the case, by the division either of the parenchyma cells in immediate contact with the epidermis, or of those forming the second or third layer beneath it. In this case, the epidermis and the one or two layers of parenchyma that are thus cut off from supplies of nutriment by the formation of cork interior to them, die and disappear, and the periderm, including the cork and the merismatic layers called phellogen, in which new cork cells are formed, now constitues the epiphlœum. It increases in thickness by the formation of new cells in the phellogen by tangential division, but at intervals rows of cells divide in a radial direction thus enabling the layer to keep pace, for a time, at least, with the growth of the stem in circumference. Examples of plants that form a periderm of this character are the Beech, Chestnut, Hazel and Bass-wood.

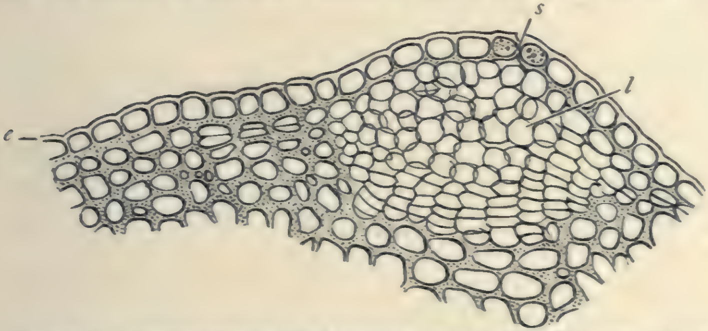


FIG. 453.—Transverse section through lenticel of the White Birch. *s*, stoma; *l*, cells of the lenticel which, by their rapid increase by fission in the inner layer, have caused an elevation of the epidermis, but have not yet burst through it; *e*, epidermis. Magnified about 280 diameters. After DeBary.

The mesophlœum beneath this layer consists largely of parenchyma cells, the outer layers of which are rich in chlorophyll. It is hence often called the green layer of the bark, for it is this which in young shoots, before the formation of a periderm, communicates the green color to the surface, the cells of the epidermis being transparent. Some stems remain green for years because of the delay to form a periderm, and the persistence of the epidermis. Menispermum Canadense affords an example.

Not infrequently there occurs at the junction of this layer with the liber a ring or zone ; it may be more or less interrupted, consisting partly of liber fibers and partly of stone cells. Sometimes where this zone crosses the medullary rays it dips inward toward the centre of the stem, thus presenting a scalloped appearance when viewed in cross-section. Clusters of stone cells may also develop elsewhere in this layer, and it may contain milk-tissues, secretion cells, secretion reservoirs, etc. In stems where the layer persists, new cells are also formed either along the continuations of the medullary rays or elsewhere, so that it keeps pace with the general expansion of the tissues of the stem.

It is by no means always the case that the periderm originates at or near the exterior. In many woody stems it originates internally, in the deeper layers of the mesophlœum, or even in the innermost layer of cells where it joins the zone of liber fibers just described, or if that is not present, where it joins the other tissues of the liber. Thus, when the periderm is formed, not only may the epidermis disappear but also the greater part or even the whole of the mesophlœum, leaving only the liber covered with a periderm. The Juniper, Currant, Honeysuckle, Deutzia, Philadelphus and Barberry are examples of plants that form an internal periderm.

In the majority of woody stems when they become old, whether the periderm is at first produced superficially or from more deeply lying tissues, secondary formations of periderm occur in succession interior to those first formed, and the layers of dead tissues exterior to them, stretched by the growth of the stem, become ruptured or fissured in various ways and peel off from the surface. These secondary layers of periderm may be formed in the mesophlœum or in the older portions of the liber ;

hence, in the large trunks of many of our forest trees all tissues exterior to the liber have disappeared, and, in the strict sense of the term, nothing of the bark but the inner layer or endophlœum is left.

The liber is always present and always constitutes the most important portion of the bark. Although, as we have seen, its outer layers may peel off while being renewed from within, it always consists, when first formed, of the phloem of the fibro-vascular bundles, together with that portion of the medullary rays which separate these parts of the bundles laterally. It consists, therefore, largely of sieve and parenchyma tissues, with hard bast often intermingled. It not infrequently also contains other tissues, such as milk tissues, secretion cells, etc. The soft tissues of this layer are particularly rich in albuminoid and other nutritious matters, and in medicinal barks it constitutes the area in which the active principles are usually found in greatest abundance.

Since in perennial stems this layer increases in thickness year by year by growth in the cambium, it often, though not always, presents the phenomenon of rings of growth similar to those seen in the woody part of the stem.

It is not always the case that the stems of Dicotyledons conform fully to the type which has been described. Cucurbitaceous plants, like the Pumpkin and Melon, have, as we have seen, bi-collateral bundles; moreover, these bundles are arranged in two concentric circles instead of one. Other curious deviations from the typical form occur in the stems of many tropical climbers.

The stems of Gymnosperms show, for the most part, the same arrangement of the fibro-vascular bundles as those of Dicotyledons. They differ from the latter mainly in the fact that the tissues, particularly those of the xylem, are less complex. In most cases the ducts and proper wood-cells which are so abundant in the xylem of Dicotyledons are few in number or altogether wanting, these tissues being replaced, as we have seen, by discigerous tracheids.

Histology of the Leaf. The leaf consists of: (1) the *fibro-vascular system*, or framework, which was partly described in Part I, under the head of "venation;" (2) the *parenchyma*, or "filling" of the leaf; and (3) the *epidermis*, which covers the whole.

The *epidermis* of the leaf has substantially the same structure as that of the stem, except that it is usually more abundantly supplied with stomata, particularly on its under surface. Here they are often very numerous. The leaf of Osmunda regalis has 21,000 to the square inch, that of the Apple upwards of 150,000, and that of the Olive tree more than 400,000. The ordinary epidermal cells are also more apt to have lobed or irregular forms than those of the stem, as illustrated in Fig. 405.

The *fibro-vascular bundles* of the leaf are usually composed of much the same elements as those of the stem with which they are continuous, except that in their finer ramifications they become much depauperated, being often reduced to scarcely more than a row of tracheids. They follow the course of the veins and are a constituent part of them, though the veins include other tissues than those which properly belong to the fibro-vascular system. The bundles are usually collateral and closed; the phloem portion faces the lower or outer surface, while the xylem faces the upper or inner surface. In the petiole there is either one large bundle or, more commonly, a mass composed of several pursuing a parallel course, at the stem end, becoming a part of its fibro-vascular system, and in the lamina spreading out in various ways, according to the plans of venation already described.

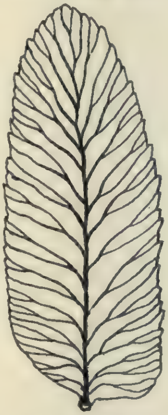


FIG. 454.—Leaflet of Osmunda regalis, showing arrangement of fibro-vascular system. Magnified two diameters.

In the forked type, seldom seen except in Ferns and their allies, the bundles may spread out from the base of the leaf and run toward the margin, in which they terminate without anastomoses, or they may diverge from a median group of bundles or midrib, as shown in Fig. 454.

The *parallel type* is, as we have already seen, the prevalent one in Monocotyledons and Gymnosperms, though in exceptional instances it occurs among Dicotyledons, as in Eryngium yuccæfolium.

It presents interesting variations. In the Pines a single median bundle is present, or two bundles enclosed in a common sheath but unconnected by cross-veins, run parallel to each other from base to apex of the leaf. In Welwitschia and most Monocotyledons the bundles run nearly parallel to each other from base to apex or margin, or from a median group of bundles, forming a midrib, to the margin. Adjacent bundles are connected laterally by minute branches which remind one of the rounds of a ladder. The ends of the veins seldom terminate free, but curve toward each other and become united near the margin. See Fig. 455. A few exceptional Monocotyledons belonging mainly to the Yam, Arum and Smilax families, have the bundles reticulately arranged, as in most Dicotyledons.

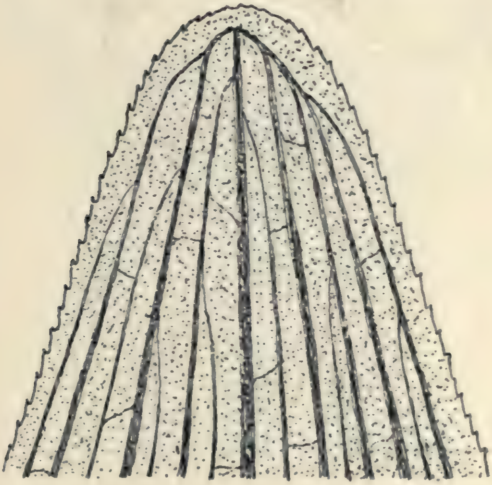


FIG. 455.—Apical portion of leaf of Smilacina stellata. Magnified about 30 diameters to show arrangement of fibro-vascular bundles.

In the *reticulate type* the bundles that enter the blade branch freely through it, running in all directions and anastomosing to form a net-work. The net-work may be fine or relatively coarse, but the meshes are seldom very regular, except in some Ferns which exhibit this type of venation. In many cases there are bundles which end free in the interior of the meshes, as in Fig. 456; in others these are wanting, but some of the veins terminate free in the margin; in still other cases both modes occur in the

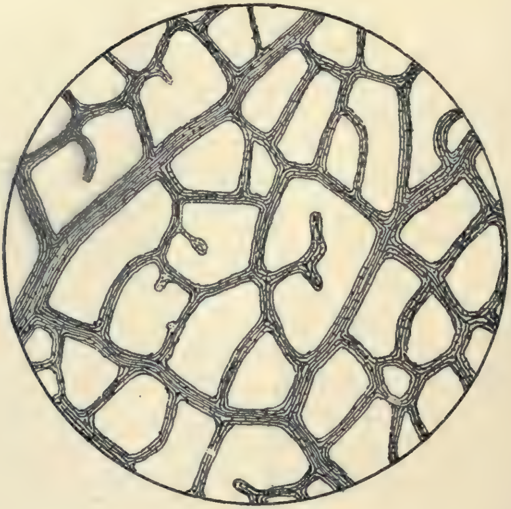


FIG. 456.—Part of fibro-vascular system of leaf of Cobæa scandens. Magnified 30 diameters.

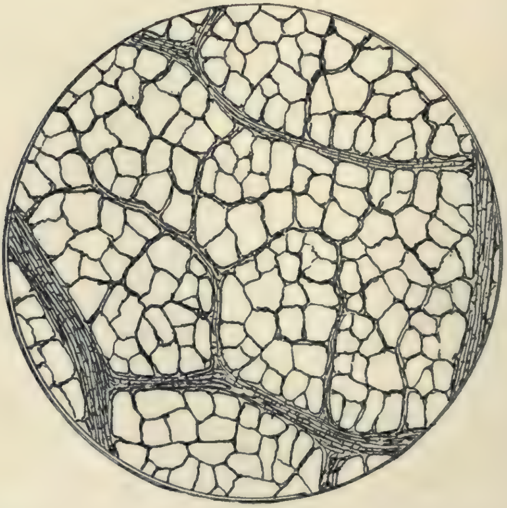


FIG. 457.—Part of fibro-vascular system of Bass-wood leaf. Magnified 30 diameters.

same leaf. Compare Figs. 456 and 457. The main veins from which branches diverge to form the reticulum may be pinnately, radiately or costately arranged. In netted leaves the veins are usually more prominent on the dorsal surface of the leaf.

The *parenchyma* or *mesophyll* of the leaf is arranged differently in different leaves, two different types of arrangement being distinguished: (1) the *bi-facial*, where it is compactly arranged against one surface, usually the upper or ventral, and more loosely farther interior and against the other surface; and (2) the *centric*, in which the distribution is nearly uniform throughout.

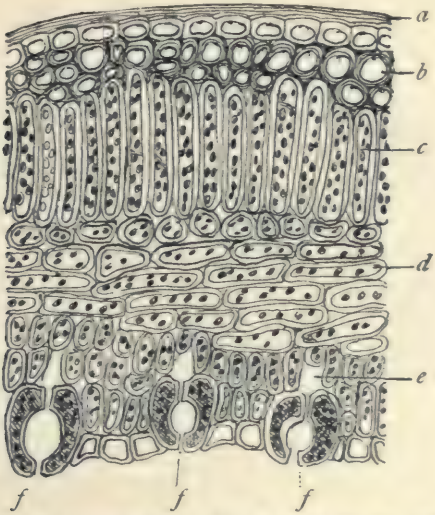


FIG. 458.—Portion of transverse section of leaf of Cycas revoluta, illustrating structure of bi-facial leaf. *a*, cuticle of the thick-walled epidermal cells; *b*, thick-walled cell of the hypoderma; *c*, palisade cells containing chlorophyll-bodies; *d*, loose interior parenchyma; *e*, large inter-cellular space over stoma; *f f f*, stomata. Magnified about 110 diameters.

The *bi-facial* is much the more common. In this there are usually two or more layers of parenchyma, rich in chlorophyll, compactly arranged next the upper epidermis, or next the hypoderma, if the latter is present. These cells are elongated in a direction perpendicular to the surface of the leaf, and hence the name *palisade tissue* has been applied to them. The other parenchyma cells of the leaf are usually very loosely arranged, being separated from each other by large intercellular spaces. They are hence called *spongy* parenchyma. In leaves of this class, the color of the upper surface, owing to the compact arrangement of the chlorophyll-bearing parenchyma cells next to it, is usually a much deeper green than that of the lower surface.

The *centric* arrangement does not ordinarily occur, save in leaves that are considerably thickened, as in those of Aloes and Crassula, and in leaves which, like those of the Pines, do not present a distinct upper and under surface.

In all leaves, the stomata are placed directly over an intercellular space, so that there is free communication between the interior of the leaf and the outside. Fig. 458 represents a portion of the cross-section of a bi-facial leaf, that of Cycas revoluta, and Fig. 459 represents the cross-section of a centric leaf, that of a species of Pine.

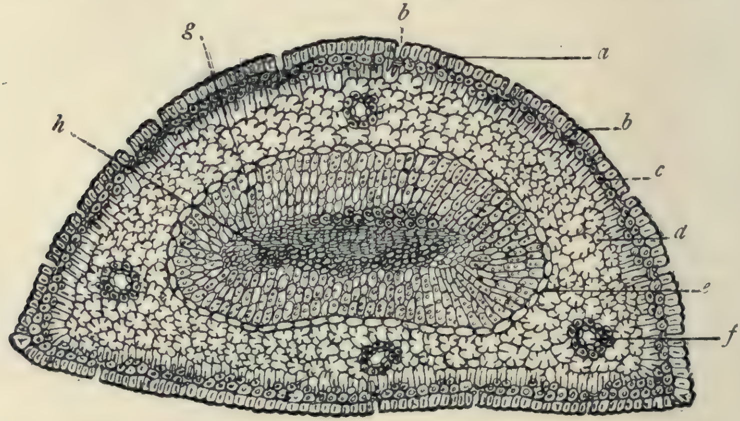


FIG. 459.—Transverse section of a centric leaf, that of a Pine. ***a***, epidermal cells, excessively thickened; *b b*, stomata; *c*, thick-walled hypodermal cell; *d*, chlorophyll-bearing parenchyma cells with walls much folded internally; *e*, endodermis; *f*, secretion reservoir; *g*, pitted parenchyma cells: *h*, xylem of a fibro-vascular bundle. Magnified about 50 diameters.

As regards the **Histology of the Floral Organs,** it corresponds in a general way with that of the organs of vegetation from which they are derived. They are, however, morphologically degenerate structures, and hence, on the whole, have less complex tissues. Floral leaves, unless they contain chlorophyll, develop few stomata or frequently none at all, and the epidermis generally is a less complicated structure than that of ordinary leaves. Its cells often contain a diffused liquid coloring matter or less frequently, solid colored corpuscles. The velvety appearance of some petals and sepals is due to the conical form of the epidermal cells, which are so arranged that the apices point outward. The fibro-vascular system of floral organs is also usually simpler than that of ordinary leaves. The minute structure of the essential organs of the flower has already been sufficiently described in Part I to answer the purposes of this work.

PRACTICAL EXERCISES.

1. For the study of open collateral bundles, make sections transverse and longitudinal of a stem of Menispermum Canadense, selecting one that has attained a season's growth. This is selected for the first study, because the fibro-vascular bundles are sharply distinct from the other tissue systems, the medullary rays being broad, unlignified and composed of thin-walled cells, and the various kinds of tissues of the bundles are well developed. It also affords a simple and easily understood example of the Dicotyledon type of stem structure. The sections should be cut thin, and care should be taken that the longitudinal ones run as nearly lengthwise of the grain as possible. To get a clear understanding of the structure, some of the longitudinal sections should be radial and others tangential. A radial section, it will be remembered, is one which passes through the middle of the stem lengthwise,—that is, along the medullary rays,—while a tangential section is made to one side of the centre, so as to cross the direction of the medullary rays. The sections used for immediate study should be placed on a slide, treated with a drop of phloroglucin solution, and then, after the solution has had time to thoroughly penetrate the tissues, but before the liquid has evaporated from the cells, put on a drop of chlorhydric acid, cover the section with a cover-glass and examine. The tissues of the xylem, the bast cells of the phlœm and other lignified tissues will, by this process, be stained a bright red, while the unlignified tissues, such as most of the pith cells, the medullary ray cells, the cortical parenchyma, the sieve tissues and the cambium cells will not be stained.

Some of the longitudinal sections should be treated with Schultze's maceration fluid for the purpose of isolating the tissues and studying them in detail.

Those sections which it is desired to mount permanently should first be treated with alcohol, 70%, for several hours, and then double-stained as follows: Soak the sections for about half an hour in a solution of iodo-methyl-green; then afterward, for a similar length of time, in ammonia-carmine solution; then they should be rapidly rinsed in distilled water, transferred first for a short time to weak alcohol, and then, as rapidly as possible without causing shrinkage of the sections, to stronger, and finally to absolute, or at least 98% alcohol. Here they should remain for about half an hour, until nearly deprived of water, when they are to be transferred—first, to oil of turpentine for a few minutes; then, for half an hour or more, to oil of cloves, and then, finally, monnted in Canada balsam. Thus prepared, the tissues will be well differentiated, and may easily be studied.

Beautiful differential staining may also be produced by placing the sections as soon as cut, in Hanstein's Rosanilin Violet, and letting them remain a short time, or until sufficiently stained. They may then be anhydrated and mounted in balsam, as directed above, or without anhydration they may be mounted in glycerin jelly.

After the structure and arrangement of the tissues and tissue systems of this stem are well understood, similar studies, for the sake of comparison, should be made of twigs of the Bass-wood, Apple, Maple, Witch Hazel, or other common woody plants, and the resemblances and differences of structure carefully noted and described by the aid of drawings.

The stems of several herbaceous Dicotyledons, such as those of the Begonia, Buckwheat, Datura, Cow Parsnip and Common Milkweed, should now be studied in the same way.

Make similar studies, also, of the stems of aquatic Dicotyledons, such as the Water Chinquepin, the White Water-lily, the Yellow Water-lily, etc.

In what respects do the fibro-vascular bundles of the above-named stems of herbs and aquatics differ from those of the woody stems you have studied?

2. For the study of bi-collateral bundles, make thin sections of stems of the Pumpkin, Squash or common Watermelon, and study them in a similar manner. Compare these with sections of the stem of the Yellow Dock.

3. For the study of the Monocotyledon type of stem structure, first make thin sections of the stalk of the common field Corn, treating the sections in the same way as it was directed to treat those of Menispermum. Note the distribution of the bundles, and then study their structure, the relative arrangement of xylem and phloem, the tissues composing each, and determine whether or not they are separated from each other by a cambium area; study what tissues of the stem are lignified, and what ones unlignified, and note the tissues of the hypoderma, observing whether they are fibrous or not, the extent to which their walls are thickened, etc.

Now compare with this, sections of the stems of other herbaceous Monocotyledons, such as the Spiderwort, Canada Lily, Tuberose, and Wheat.

Compare, also, sections of the stem of a woody Monocotyledon, as that of Smilax or Rattan, and note carefully the structural differences.

Lastly, compare sections of aquatic Monocotyledons, such as Pickerel Weed, Bulrush, and Calamus.

4. For the study of the concentric bundle and the Fern type of stem, make similar studies of the rhizome of Pteris aquilina, of Aspidium marginale, and of Polypodium vulgare.

5. For the study of radial bundles and root structure, first make sections of the rootlets of the Sweet Flag or Calamus, or of the Virginia Spiderwort, preparing sections as before. Identify the xylem rays and the alternating phloem masses; determine the number of each, and the tissues which compose them. Identify the pericambium zone and the endodermis, and study the character of the cells which compose each of them.

With these, compare sections of the roots of other Monocotyledons, such as those of Indian Corn, Amaryllis, Indian Turnip and Calla, making drawings and descriptions of the central fibro-vascular bundles in each case.

Make similar sections and studies of the root of some herbaceous Dicotyledon, such as that of the common Buttercup, or of the American Cowslip, and of some Fern, such as Osmunda cinnamomea, and observe that in all essential respects the structure is the same as that of the roots previously studied.

Now cause a few beans or peas to germinate, and make transverse sections of the primary root in different stages of its development. Note that, when young, its structure corresponds with the rest, but afterward it undergoes important secondary changes. By means of a series of sections, study the successive stages of these changes, recording your observations by aid of drawings.

6. For the study of the arrangement of fibro-vascular bundles in leaves, obtain the following: the fork-veined leaflets of the Cinnamon Fern or of the Maiden-hair Fern; the parallel-veined leaves of the Lily-of-the-Valley or of Solomon's Seal; and the reticulate leaves of the Wild Cranberry, of the Maple and of the Wild Cucumber (Echinocystis). In order that the finer ramifications of the veins may be distinctly seen, it is best that the leaves should first be bleached and then stained. Soak them for a few days in alcohol to remove the chlorophyll, then transfer them to Labarraque's solution, and let them remain until colorless, but not so long as to cause their disintegration. They must now be soaked for some time in clean water, or better, be allowed to remain for some hours in running water, until the last traces of the odor of chlorine have disappeared. They should then be allowed to stand for a little time in water slightly acidulated with hydrochloric or nitric acid, and then transferred to a very dilute aqueous solution of methyl-green and permitted to remain until the veins have become distinctly stained. They may then be rinsed in clean water and examined. The lignified tissues of the veins are more deeply stained by this process than the rest of the structure, and the fibro-vascular system may, therefore, be readily traced. Such preparations may be mounted in balsam, and if the preparations are not much exposed to light, the aniline stain will persist for years.

7. For the study of the internal structure of bifacial leaves, take almost any flattened leaf, like that of the Currant, Beech, or American Elm, and place it between two pieces of Elder pith and make thin slices transversely, with a razor, transferring the sections to water as fast as made. By aid of a camel's hair brush, float some of the thinnest ones upon a slide, cover with a cover-glass and examine. Observe the vertically elongated palisade cells beneath the upper epidermis, the loosely arranged parenchyma farther interior, and the somewhat more compactly arranged parenchyma next the lower epidermis. In the lower epidermis, also, a side view of stomata may be obtained. Observe that these each communicate with a large intercellular space. Study the section of a vein, and observe what kind of bundle it represents, also the position of the phloem, as respects the lower epidermis.

By a similar method, the structure of centric leaves may be studied. For this purpose, leaves of the Wax-plant (Hoya caruosa), or of the garden Portulacca, may be used. Here, it will be observed, no distinct palisade tissue is developed, and there is little difference of structure between the upper and under sides of the leaf.

Now compare with these the leaf of the common White Pine, making thin cross-sections of it and studying it with care. Does it represent the bi-facial or centric type? Observe the excessively thick-walled epidermal cells, the well-developed hypoderma, the large intercellular spaces beneath the stomata, the peculiar chlorophyll-bearing parenchyma cells with internally folded walls, the scattered resin-passages, and the pitted parenchyma cells and fibro-vascular bundle, both enclosed within the bundle sheath. Make drawings and careful descriptions of each of the leaves studied.

8. For the study of sepals and petals with reference to the venation, the presence or absence of stomata, the character and distribution of the coloring matter and the cause of the velvety appearance which some parts possess, the flowers of Tropeolum majus, of Torenia Asiatica and of the common Pansy may be selected. Cross-sections may be made in the same manner as was directed for ordinary leaves.

APPENDIX TO PART II.

USE OF THE MICROSCOPE IN VEGETABLE HISTOLOGY.

Kind of Microscope Required. It is a mistake to suppose that a complex and costly instrument is essential to obtaining a good knowledge of vegetable histology. The optical parts must, of course, be of good quality, but it is better that the stand should be simply constructed, for its use will then be more easily learned and there will be fewer parts liable to get out of order. A stand of small size, built after the so-called continental model, is far preferable to the larger English and American ones, both because it is more convenient to handle, and because, in much of the work required to be done it is better, on account of the frequent necessity of applying reagents to the tissues undergoing investigation, to have the stand in the upright position with the stage horizontal. To work with the instrument upright, if the stand is a large one, is both inconvenient and tiresome.

Referring to Fig. 460, the parts of a compound microscope are as follows: *A* is the eye piece, which, in its usual form, consists of two plano-convex lenses, mounted in a metal tube, the one placed next the eye, called the *eye-lens*, and the one farthest from the eye, the *field-lens; B* is the *objective*, consisting of a combination of lenses mounted in a metallic frame, and the rest of the instrument is called the *stand*. Of the latter, the tube or combination of tubes which hold the optical parts, is called the body; this ordinarily consists of two parts, the *tube T*, and the *sleeve*, *C*, in which the tube slides. The sliding of the tube within the sleeve constitutes, in this case, the *coarse adjustment* or means by which the microscope is approximately focused. Supporting the body is the arm, *D;* this is surmounted at the top by a *fine adjustment* screw, *E*, by means of which the body may be moved slowly up or down, so as to bring the object accurately into focus. Rigidly attached to the basal part of the arm, and with its plane at right angles to the axis of the body, is the *stage*, *F*, on which the object to be studied is placed. The stage has a central aperture for admitting light from below, and, on its upper surface, is provided with two *spring clips* to secure the slide that holds the object. Attached to the under surface of the stage is a revolving *diaphragm*, *G*, perforated with apertures of various sizes to regulate the amount of light admitted to the objective. Below the stage is the *mirror*, *H*, to reflect light upward through the aperture in the stage upon the object. The part of the stand which supports the stage, arm and body, with the optical parts, is called the *pillar*, *J*, and this, in turn, is supported by a heavy piece of metal called the *base*.

The requisites of a microscope suitable for a course in vegetable histology may be summed up briefly as follows:

1. The stand should be well proportioned and solidly constructed, so that it will be firm and not liable to get out of order.

2. The stage should not be so high above the base that the object cannot readily be manipulated on the stage while the hands are resting upon the table.

3. It is a convenience, though not a necessity, to have the stand so constructed that the body may readily be inclined at any angle from the perpendicular to the horizontal. For use with some forms of the camera lucida and for photography it is also convenient if there be a stop at the horizontal.

4. The stage should be firm, perfectly flat on its

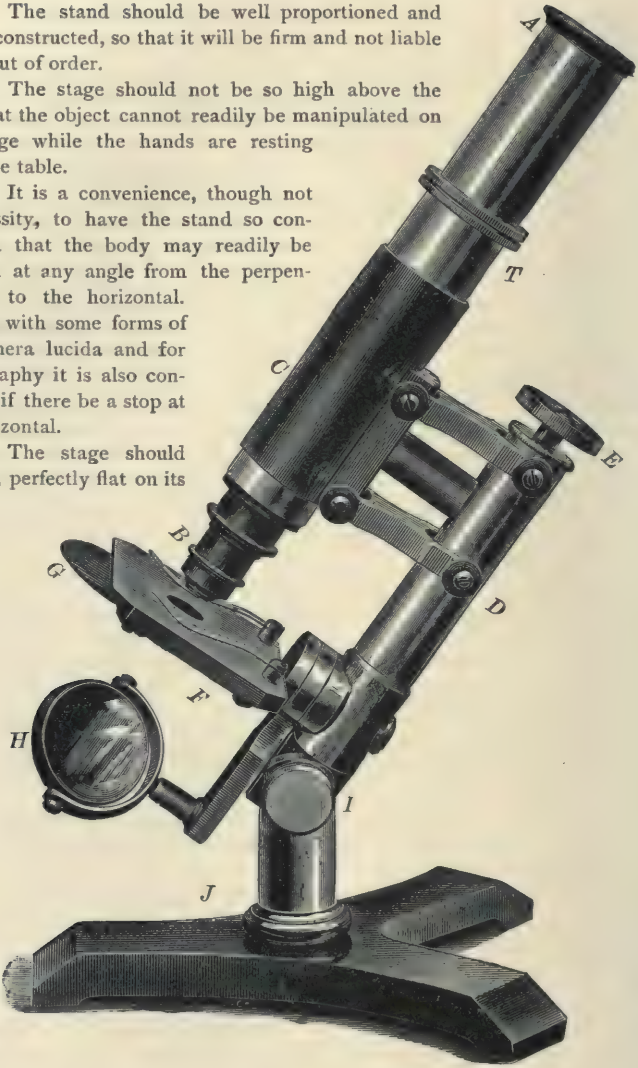


FIG. 460.—*A*, Eye-piece. *B*, The objective. *C*, The sleeve. *D*, Arm supporting the sleeve and tube. *E*, The "fine adjustment," operated by a screw, for obtaining the exact focus *F*, The stage, with a pair of spring clips to hold the object or slide. *G*, A revolving diaphragm, with perforations of various sizes to regulate the amount of light admitted to the objective *H*, A concave mirror on an axis, which permits illumination of any obliquity beneath the stage. It swings on an arm, by which it may be brought above the stage for the illumination of opaque objects. The instrument, complete without the objective, is called the "stand."

upper surface, but not too thick to admit of considerable obliquity of illumination, and it should not be less than about three inches wide.

5. The coarse adjustment had better be by sliding tube, as the rack-and-pinion when well made is expensive, and when not well made is very liable to get out of order and render the stand next to worthless. For the fine adjustment a micrometer screw is necessary, and this should be very carefully constructed so that it will last well and produce no lateral motion even when used with the highest powers.

6. The stand should afford room enough between the stage and the front end of the tube, when the latter is drawn out to its extreme limit, to admit of the use of an objective of as low a power as a three-inch, if desired.

7. While most of the work of the student will be done with the tube shortened to six and one-eighth inches (155 mm.), as in the continental model stands, it is a convenience if the body be provided with a draw-tube, so that it may be extended to ten inches, the standard English length of tube. The magnifying power may then be varied within certain limits without changing the optical parts.

8. There should be a diaphragm beneath the stage, for the purpose of increasing or diminishing the amount of light admitted to the objective.

9. The reflecting mirror beneath the stage should have a concave surface whose focus is not far from the level of the stage, and the mirror itself should have a diameter of not less than an inch and a fourth. It should also be so mounted as to be capable of convenient adjustment at any angle. It is an advantage, also, if the mirror is mounted on an arm or bar capable of swinging vertically on an axis which lies in the same plane as the stage (see illustration), so that light may be directed upon the object from any point below or above the stage. Such an arrangement saves the additional expense of a bull's-eye condenser for the illumination of opaque objects.

10. The optical parts, both objectives and eye-pieces, should be of good construction. The form of eye-piece called the Heyghenian is the best for regular work. The objectives should give a flat field, clear and sharp definition of the object, and be practically free from color aberration, even when used with an eye-piece of one-inch focal length.

11. Much the larger proportion of all the work the vegetable histologist is called upon to do may be done with powers ranging from thirty to about seven hundred diameters. No higher powers than these are necessary for the work laid out for the student in these chapters. These may be obtained, approximately, by means of two eye-pieces, one having an inch and a half and the other an inch focal length, and two objectives, the lower power having a focal length of one inch or two-thirds inch, and the higher a focal length of one-sixth or one-eighth inch.

ACCESSORY APPARATUS.

The following may be regarded as necessities:

A pair of *delicate forceps* or *tweezers* for handling sections, minute pieces of tissue, etc.

A pair of *sharp-pointed scissors.*

A good sharp razor or other suitable knife, for making thin sections of objects for microscopic study.

A pair of *sewing needles* having their heads forced into wooden handles, to serve for the dissection of tissues.

A small *camel's-hair brush* for transferring sections to a slide, and generally for the manipulation of small objects or structures of delicate texture.

A *glass tube* of about one-fifth inch caliber, and a *glass rod*, each about six inches long and having the ends rounded in a flame. They are serviceable in transferring small quantities of test solutions, etc., from the containing bottles to the object to be tested.

A quantity of *glass slides*, 3 inches by 1 inch, having ground edges, and as many square or circular *cover-glasses* of moderate thinness, and having a diameter of about ¾ of an inch.

A *rule*, graduated on one edge in inches and sixteenths of an inch, and on the other in decimeters, centimeters and millimeters.

An *eye-piece micrometer*. The form which we prefer as most convenient consists of a cover-glass, not too thin, on which one-fifth of an inch is divided into ten equal divisions, and one of these spaces near the middle of the scale is subdivided into ten equal parts, as shown in Fig. 461. The lines should be cut rather deep and filled with black-lead ; the cover glass should then be mounted in balsam, the ruled side downward, on a clear piece of somewhat thicker glass, ground to such dimensions that it will fit easily inside the eye-piece and rest on the diaphragm between the two lenses. Such an eye-piece micrometer may also be made to answer all the ordinary purposes of a stage micrometer by attaching it to an ordinary glass slide by means of a little water. It will be held with sufficient firmness by the capillary attraction.

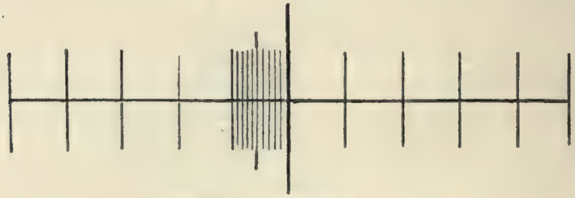


FIG. 461.—Eye-piece Micrometer.

A *camera lucida*, as an aid in drawing. A simple and inexpensive form, though less convenient to use than some others, because it is necessary that the microscope tube be in the horizontal position, is the neutral tint camera lucida, which consists essentially of a piece of neutral tint glass placed immediately back of the eye-lens at an angle of 45° with the axis of the microscope. But the camera lucida which we prefer above all others, is the Abbé, illustrated in Fig. 462 and manufactured by Carl Zeiss of Jena. The instrument is fastened upon the eye-piece by means of the clamp-screw at the left. The drawing surface is made visible by double reflection from the large plane mirror at the right and from the silvered surface of a small prism placed in the visual point of the eye piece. In the middle of the silvered surface of the prism is a small aperture, smaller than the pupil of the eye, through which the microscopic image is seen directly at the same time that the pencil and paper are perceived by the double reflection. This camera has the advantage that it is used with the microscope in the upright position.

The following pieces of apparatus, though useful, are not really indispensable for such a course as here laid down :

A *microtome*, for cutting sections accurately and uniformly of a given thickness. A complicated and expensive form is not desirable.

A *turn-table* as an aid in mounting objects.

A good *magnifying glass* of about one inch focus, so mounted that it may be adjusted to focus, and that both hands may be left free for manipulating the object. The low power objective will serve the purpose of such a lens, and the student may readily devise for himself a stand for it which will serve the purpose. Such an instrument is useful in preparing tissues for examination with the compound microscope, for making dissections in the preliminary study of certain structures, etc.

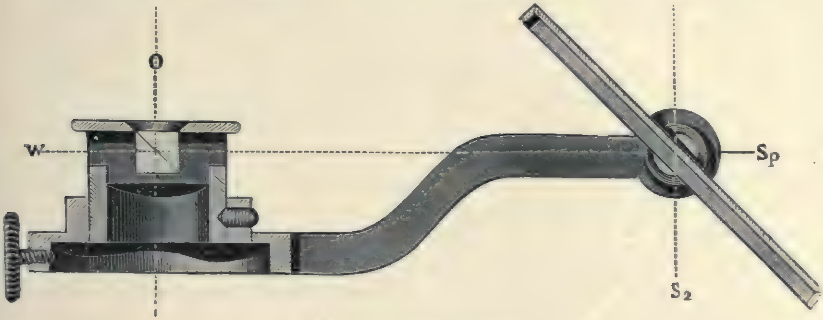


FIG. 462.—Camera Lucida.

MICRO-REAGENTS.

Iodine Solution. One of the most generally useful iodine preparations is the following :

Saturate a small quantity of distilled water with iodide of potassium, then dissolve in it all the metallic iodine the solution will take up, and afterward dilute the solution until it has a rich sherry color. It stains starch blue and protoplasm a yellowish-brown. It also stains lignified tissue a brownish color. As a test for starch-grains in cells, the solution should be used quite dilute, otherwise the grains will be so deeply colored as to appear black. Along with sulphuric acid it may also be used as a test for cellulose tissues as follows : Treat the section first with the iodine solution for a few minutes, and then with a mixture of two volumes of strong sulphuric acid to one of water. The cellulose tissues will slowly acquire a purple color, while lignified tissues will be stained brown.

Solutions containing iodine should be excluded from the light to prevent the formation of iodic acid.

Chloriodide of Zinc Solution. This is prepared as follows: Dissolve zinc in pure hydrochloric acid until saturated, then evaporate the solution in contact with zinc until it has a syrupy consistence, then saturate it with potassium iodide, and, lastly, with metallic iodine. Keep the solution in an amber-colored glass-stoppered bottle. Used in the undiluted form, it constitutes one of the best tests for cellulose and lignified tissues, staining the former a purple and the latter a brown color. Suberized or cutinized tissues are also stained by it a yellowish brown. Starch grains are first stained blue and then rapidly swell and disappear. The peculiar form of cellulose found in fungi remains uncolored, both by this reagent and by iodine and sulphuric acid.

A very dilute solution of chloriodide of zinc is used as a test for tannin, cells containing this substance being colored violet or red by it.

Potassium Hydrate. This is one of the most useful of reagents. Its value depends, in the main, on its solvent effects upon proteid matters and starch, and on its power to cause cell-wall tissues to swell, but it is also serviceable as a test for tannin, for cutinized tissues and for some other purposes. It is best obtained in sticks and kept in tightly stopped bottles until required for use, as upon exposure it takes up carbon dioxide and water from the air, and becomes converted into the carbonate. When a solution is required for use, remove a small piece from the bottle, dip it for a moment in water to remove the film of carbonate and dissolve the remainder in a fresh portion of distilled water. For some purposes a dilute solution is required, for others it must be used strong. As a clearing agent for dissolving cell contents a five per cent. solution is best. A section which has soaked for some time in the reagent is placed on a slide, the potash neutralized with a drop of acetic acid, when it will be found ready for study. For the study of the markings of starch grains a one or two per cent. solution is applied to the edge of the cover glass, and allowed to run under by capillary attraction; in the meantime the changes in the starch grains should be carefully watched. They first swell slightly and the markings are revealed with great distinctness, but as further swelling takes place they disappear and the grains themselves soon become disorganized. When a five or six per cent. solution is used the lamination of thick-walled cells is often brought out with much greater distinctness. As a reagent for suberized or cutinized tissues a strong solution should be used. It communicates a yellow color to such tissues, which deepens if the slide is warmed, and if heated so that the solution boils the suberin exudes in the form of yellow drops. A strong solution is also best as a test for tannin. The tannin is recognized by the yellow or yellowish brown color which is produced by this reagent. The ferric chloride test for tannin is, however, to be preferred. Caustic potash solution in dilute form is also useful as a means of distinguishing between protein crystals or crystalloids and crystals of inorganic matters. The former immediately swell and lose their angles, while the latter are unaffected.

A very good form of this reagent is *Russow's Potassium Hydrate.* A small quantity of a concentrated solution of potassium hydrate in distilled water is prepared. This is added to ordinary alcohol until a precipitate begins to form.

After repeated agitation, it is set aside for twenty-four hours; the clear liquid is then decanted and mixed with two volumes of distilled water. It should be kept in a close-fitting, glass stoppered bottle, the stopper of which has been dipped in vaseline to prevent it from sticking. It may be used in the same manner as the aqueous solution, by diluting it to suit the special requirements of the case. It has the advantage of keeping better than the ordinary watery solutions.

Phloroglucin. Make a two or three per cent. solution in alcohol. It is the best available test for lignified tissues. The section to be tested is first treated with a few drops of the solution, and after the tissues have been thoroughly permeated by it, a drop of hydrochloric acid is applied. All lignified tissues will immediately be stained a beautiful red color, which will vary in depth according to the degree of lignification, while unlignified tissues are not stained at all. The middle lamella of thickened cell-walls is often beautifully differentiated from the rest of the wall because of its deeper staining.

An alcoholic solution of aniline chloride used in the same manner stains lignified tissues a bright yellow, while other tissues are unaffected.

Schulze's Maceration Fluid. This consists of strong nitric acid in which potassium chlorate has been dissolved to saturation. It acts powerfully on vegetable tissues, but dissolves the middle lamella more readily than the rest of the cell-wall, and hence is highly serviceable in isolating cells. The fluid acts more rapidly if heat is applied, but better results are obtained if the process is not hastened. It is often of advantage to dilute the solution somewhat with water and let the tissues macerate for some hours. When the action has been continued long enough, the tissues become colorless, and when placed upon a slide and covered with a cover-glass, if the latter be gently tapped with a needle-point the cells will readily separate.

This reagent is also useful for the detection of suberized tissue. On boiling a thin section in it, the corky tissues will be found to resist the action of the reagent longer than the rest, but finally the cells swell up and their walls liquify, forming an oily looking liquid called ceric acid. The test applied in this way serves well for demonstrating strongly suberized tissues, but is not sufficiently delicate for slightly suberized ones. These may be identified as follows: Soak the section for a few moments in the cold fluid and then remove it to solution of potassium hydrate; the suberized tissues will immediately assume an ochre-yellow color.

Nitric Acid. This reagent is generally used in the concentrated form. It immediately kills protoplasm, and causes it to shrink away from the cell-wall, and if ammonia or potassium hydrate be afterward applied, the proteid cell contents assume a yellow color.

If a section containing thick-walled tissues be treated with hot nitric acid and afterward with ammonia, the middle lamella will be stained yellow.

Sulphuric Acid. Strong sulphuric acid dissolves starch and cellulose, converting the former into dextrin and the latter into amyloid, a substance which, like starch, acquires a blue color with iodine. It dissolves protoplasm and other albuminoids much more slowly, hence it is is used for demonstrating the continuity of protoplasm from cell to cell in certain tissues. It also stains cuticularized tissues brown, when used in connection with iodine, but does not dissolve them, hence it may be used as a test for them. Cells containing protoplasm, if first treated with a solution of cane sugar and then afterward with sulphuric acid, acquire a rose-red color.

Acetic Acid (Glacial). This acid, in two per cent. aqueous solution, is serviceable for defining the nucleus; when used strong, it is a valuable clearing agent, dissolving the cell-contents and rendering the cell-walls more distinct, and it is useful as a means of distinguishing between deposits consisting of calcium carbonate and those composed of calcium oxalate or silica, since calcium oxalate is dissolved by it with effervescence, while both of the other substances are insoluble.

Hydrochloric Acid. Besides its use in connection with phloroglucin and aniline chloride in testing for lignin, it is more or less serviceable as a clearing agent, and is useful in distinguishing between calcium carbonate and calcium oxalate, both being soluble in this reagent, but the former with effervescence and the latter more slowly and without effervescence. A one-fourth per cent. solution of the acid in 70 per cent. alcohol is also serviceable in reducing the color of sections which have been overstained in carmine or hæmatoxylin solutions.

Cuprammonia. This is the only known reagent capable of dissolving cellulose without producing chemical change in it. It is prepared by adding to an aqueous solution of cupric sulphate an aqueous solution of sodic hydrate, collecting the precipitate which forms, by allowing it to settle and decanting the supernatant liquid, and dissolving it in ammonia. Pure cellulose tissues readily dissolve in it, but lignified ones do not. The undiluted solution should be used.

Mercuric Chloride. Make a two per cent. solution of the crystals in strong alcohol. It has the property of hardening albuminoid compounds and rendering them insoluble in water. On this account it is used for the study of aleurone grains. The sections to be studied should be soaked in the solution for from twelve to twenty-four hours. They may then be stained and examined. Specimens thus treated should not be handled with metallic forceps.

Alcohol. Alcohol is one of the most indispensable of reagents in vegetable histology. One important use it has is in the preservation of tissues. For this purpose 70 per cent. alcohol has sufficient strength. But it is often desirable at the same time to harden the tissues for section-cutting. For this purpose strong alcohol, 95 to 98 per cent., is often necessary. If, however, the tissues are very delicate, they must not be immediately placed in alcohol of this strength, but gradually transferred to it through graduated solutions of increasing strength.

Alcohol also dissolves chlorophyll and other coloring matters together with resinous substances, and so acts as a bleaching agent. Since it coagulates and destroys the vitality of protoplasm, without seriously impairing its structure, it is useful in preparing cells for the study of cell contents. Living protoplasm is so transparent as to be nearly invisible, and it also refuses to take up most staining materials; but after treatment with alcohol, it may readily be stained with carmine, eosin, hæmatoxylin and various other solutions.

Alcohol is also indispensable as a means of anhydrating tissues, preparatory to mounting them in Canada balsam or other oleo-resinous mounting fluids. For this purpose strong alcohol, at least 98 per cent., is required.

The presence of inulin in tissues may also be demonstrated by its use. Tissues containing it are soaked in strong alcohol for seven or eight days, which causes the inulin to be precipitated in the cells in the form of sphere crystals.

Sulphuric Ether. This is useful chiefly as a solvent for fats in the study of organs like seeds, which often contain these matters in abundance.

Glycerin. This is serviceable for clearing sections, as a preservative medium, and as a medium for the permanent mounting of tissues, though for the latter purpose glycerine jelly is in almost all cases to be preferred. It renders cell contents more transparent, and hence facilitates the study of cell walls. A mixture of equal parts of glycerine and alcohol is useful for macerating hard tissues that have been preserved in alcohol preparatory to sectioning. They should be transferred to the mixture from twelve to twenty-four hours previous to sectioning.

Ferric Chloride Solution. This consists of a rather dilute aqueous solution to which a drop of nitric acid has been added. It is one of the best tests for the presence of tannin in cells. If a drop be applied to a section containing it a blue-black or a greenish-black precipitate will be produced in the cells.

Fehling's Solution. This is prepared as follows: Dissolve 34.64 grams of pure copper sulphate and 200 grams of Rochelle salt in the smallest possible quantity of distilled water. Also dissolve in 600 cu. cm. of distilled water a sufficient quantity of sodic hydrate to make a liquid having the specific gravity of 1.12. Keep the solutions separately in well stopped bottles until required for use. When required as a test for sugar, mix one part of the former with two of the later liquid. This constitutes one of the best and most convenient tests for detecting sugars in tissues, and for distinguishing between the saccharose and the glucose groups of sugars. To apply the test dip a moderately thick section of the tissue in the boiling hot solution for two or three seconds. If grape-sugar be present the cell-contents will have been colored red from the precipitation of the sub-oxide of copper, but if cane and not grape-sugar is present a bluish or greenish color will be produced in the cells, but at first no red precipitate. On soaking the section, however, in the hot solution for a longer time a red precipitate gradually appears, because a part of the cane-sugar is converted into invert sugar.

Labarraque's Solution (Sodium Hypochlorite). It is prepared as follows: Intimately mix four parts of good chlorinated lime with fifty parts of water, and in fifty parts more of boiling water dissolve five parts of sodium carbonate. Mix the two liquids while the latter is still hot, and cover the vessel tightly. After the solution has cooled add twenty-five parts more of water and then allow it to stand until all sediment has settled. Draw off the clear solution and preserve in well stopped bottles protected from the light. The solution is very useful in destroying cell-contents and in bleaching tissues. If sections which have been bleached by it are afterwards to be stained they must first be very thoroughly washed to remove all traces of the bleaching agent.

Picric Acid. Besides its usefulness in staining certain structures, particularly in combination with carmine or certain of the aniline dyes, it is of value in fixing the protoplasmic contents of cells, and preparing them for study. For ordinary tissues a saturated watery solution is to be preferred. In this the fresh tissues, first cut into pieces of small size, so that the liquid will readily penetrate them, are soaked for twenty-four hours. They may then be thoroughly washed, stained and examined. But if not immediately required for use they should first be well washed in clean water, then transferred to 50 per cent. alcohol, then, after a few hours, to stronger alcohol, and, finally, to 98 per cent. alcohol, in which they may be kept until required for use.

A saturated solution of picric acid in a mixture of equal parts of alcohol and water is a very serviceable hardening and fixing agent, particularly for the study of algæ.

Carbolic Acid, when dissolved in water or in alcohol, is of value as a clearing agent, often producing excellent results, particularly in the study of pollen grains.

Chloral Hydrate, in watery solution, is also a good clearing agent for the study of pollen grains, and when used in the proportion of three parts of the chloral to two of water it is excellent for removing the coloring matter from chlorophyll-bodies. If afterwards a little iodine solution be added to the preparation the starch grains enclosed by the chlorophyll-bodies will be stained blue and rendered distinctly visible.

Diphenylamine. This is used as a reagent for the detection of nitrates or nitrites in tissues. A solution is prepared by dissolving one part of diphenylamine in 360 parts of pure sulphuric acid. If a drop of this be applied to a section containing either nitrates or nitrites a deep blue coloration, due to the formation of aniline blue, will be produced in the parts of the section which contain these salts.

STAINING FLUIDS.

The staining fluids of most value to the student are the following:

Grenacher's Alum Carmine. Prepare a two per cent. solution of ammonia alum in distilled water, and in this boil a little powdered carmine for about twenty minutes, so as to produce a deep red solution. After the solution has cooled filter it and add a trace of carbolic acid to preserve it. It stains cellulose a fine red color, but less readily strongly lignified tissues and suberized tissues not at all. When allowed to act for some time, say from twelve to twenty-four hours, upon cells containing protoplasm, the latter is stained, and the nucleus more strongly than the rest. The stain works best upon tissues which have lain for some time in alcohol and then have been washed with water. By a judicious use of the ¼ per cent. solution of hydrochloric acid in 70 per cent. alcohol the stain may be removed from the cell walls, leaving only that in the protoplasm and nucleus.

Ammonia Carmine. Carmine is dissolved in strong ammonia water until the latter is saturated. It is then evaporated over a water-bath to dryness and the solid carminate of ammonia thus obtained is dissolved in distilled water in sufficient quantity to produce the requisite depth of color. This form is preferable to the one above described for use with methyl-blue for the double staining of tissues, but is not so useful for the study of protoplasm and the nucleus.

Preparations stained with carmine may be permanently mounted in Canada balsam or in Hoyer's fluid for carmine, but not in glycerine jelly.

Grenacher's Hæmatoxylin Solution. Prepare a saturated solution of hæmatoxylin in absolute alcohol and, in another vessel, a saturated solution of ammonia alum in distilled water. Mix the two solutions in the proportion of two parts of the former to seventy-five of the latter. The solution should now be allowed to stand in the light for a week, then filtered, and to every seven parts of it one part each of glycerine and methylated alcohol are to be added. After the solution has stood for some time it should again be filtered or decanted in case a sediment has been deposited.

Hæmatoxylin is one of the most useful of stains. It stains both lignified and cellulose tissues but not suberin or cutin. It is also one of the very best nuclear stains. Old solutions are to be preferred, and the best results are obtained when they are used very dilute. Acids are incompatible with this stain. As we have already seen, a ¼ per cent. solution of hydrochloric acid in 70 per cent. alcohol may be used to remove a part of the coloring from overstained sections. Sometimes beautiful results are obtained by this means, as some tissues part with the staining material more readily than others. The stain does not work well with preparations that have been kept for a long time in alcohol. Both alcoholic and picric acid preparations should be very thoroughly washed in water before staining in this solution. Either Canada balsam or glycerine jelly may be used as a mounting medium.

Methyl-Green. Dissolve enough methyl-green in distilled water to communicate to the liquid a deep green color. It stains lignified and cutinized tissues more readily than those composed of pure cellulose. The tissues take up the stain more readily if they are previously washed with water slightly acidulated with nitric acid.

Acetic Methyl-Green, which consists of a one or two per cent. solution of glacial acetic acid in distilled water, in which methyl green is dissolved until a clear blue-green color is produced, is serviceable for fixing and staining the nucleus, but the color thus obtained is not permanent.

Eosin Solution. A strong alcoholic solution is particularly useful in the study of sieve-tissues, as it stains the thin albuminoid contents of the tubes a deeper red color than the rest of the structure. It also stains protoplasm and the nucleus.

Safranin, dissolved in absolute alcohol, is serviceable as a nuclear stain in the case of specimens which have been hardened in alcohol or in picric acid solution. If hardened in the latter solution thorough washing in water is necessary before applying the stain. Sections should be left in the staining solution for from twelve to twenty-four hours, and then washed in absolute alcohol until the color is mostly removed from the cell walls, when the nuclei will be found to be finely stained and their structure clearly visible. The sections should now be transferred for a short time to oil of cloves and then mounted in balsam.

Corallin Solution. Weigh out three grains of sodium carbonate and ten grains of corallin. Dissolve the former in two ounces of water, and in this solution dissolve the corallin, and filter. Place in the bottle containing the solution a few grains of camphor to prevent the solution from spoiling. It stains cellulose and lignified tissues different shades of red, and stains sieve-callus with special brilliancy. It also stains starch grains. The colors produced by this stain are fugitive.

Hanstein's Rosanilin Violet. This is an alcoholic solution of equal parts of methyl-violet and fuchsin. It stains soft bast tissues scarcely at all, other cellulose tissues a faint violet color, hard bast fibers a deep red, lignified tissues a less brilliant red, cell-walls that have undergone the gummy degeneration a different shade of red, resins are stained blue, tannin a peculiar foxy-red, protoplasm a bluish or violet color, and the nucleus and starch grains different shades of red. It stains rapidly and is very useful in the study of vegetable sections.

Picric Nigrosin. To a saturated solution of picric acid in water, enough of a strong aqueous solution of nigrosin is added to give to the liquid a deep olive-green color. It fixes and at the same time stains the nucleus, and is especially useful in the study of filamentous algæ. Specimens should be soaked in it for from twelve to twenty-four hours. It is also serviceable as a double stain for sections of stems, roots, etc., the nigrosin being taken up by the cellulose and the picric acid by the lignified tissues. Preparations may be anhydrated and mounted in balsam, or they may be mounted in glycerine jelly.

Alkanet. An alcoholic tincture of the root is useful in detecting the presence of resins and oils, these substances being stained a deeper red by it than other cell-contents.

MOUNTING OR ENCLOSING MEDIA.

The most valuable are the following:

Canada Balsam or Balsam of Fir. This should be nearly colorless and entirely free from solid impurities. It is ordinarily best obtained in collapsible tubes from the dealers in microscopical goods. The ordinary or natural balsam, consisting of resin in solution in oil of turpentine, is preferable for most purposes to the chloroform or benzol solutions.

It must be remembered that before enclosing an object in any resinous or oleo resinous medium, it must be thoroughly anhydrated. This is somewhat troublesome, but barring the trouble, balsam mounts are among the best and most durable.

Shellac Solution. A solution of the best white shellac in absolute alcohol, filtered and evaporated down to the consistency of rather thin syrup, may also be used as an enclosing medium, but is more useful as a cement for fastening cover glasses, and for making shallow cells in which to mount certain objects.

Glycerin Jelly of good quality may be made as follows: Soak, for an hour or more, one ounce of the best French gelatine in three ounces of distilled water, then raise the temperature to nearly, but not quite, the boiling point, until the gelatine is completely dissolved; add four ounces of pure glycerin and as many drops of 95 per cent. carbolic acid, gently stirring the mixture with a glass rod, so as to mix thoroughly, but not to form air bubbles, and then allow the mixture to cool. It will soon set and form a clear, transparent jelly. If the gelatine used be of the finest quality, and perfectly free from dust, which may be insured by rinsing rapidly in cold distilled water before using, no filtering or straining will be necessary. It should be kept in a test-tube, so that when required for use it may readily be melted.

Many structures are rather better defined when mounted in glycerin jelly than when mounted in balsam, and it is also less troublesome to use, as complete anhydration is not necessary. Delicate structures must not, however, be transferred immediately to the glycerin jelly, for this would cause the cells to collapse by osmosis, but they are first removed to very dilute glycerin and then successively to solutions of gradually increasing strength, until strong glycerin is reached, after which they may safely be enclosed in the medium. A more convenient method is to place the object in very dilute glycerin and permit this to gradually concentrate by the evaporation of its water. Still another way, and a good one, is to place some strong glycerin in a test-tube, say enough to fill it half full, then pour on its surface enough water to make a thin layer over it, taking care to mix the liquids as little as possible. The object is then carefully placed in the water and the tube allowed to remain undisturbed for a few days. It will then be found that the object has settled into the strong glycerin so gradually, that no damage has resulted to it from osmosis. This method is a very convenient and successful one for filamentous algæ.

Carmine-stained preparations are unsuited to this medium as the carmine is soluble in it. The same is true of some of the anilin preparations. Hæmatoxylin-stained specimens keep well in the medium, providing it contains no trace of acid.

Hoyer's Fluid for Anilin Preparations. This is made as follows: A tall wide-mouthed vessel is filled two-thirds full with the best selected gum Arabic. The vessel is then filled to the neck with a 50 per cent. solution of potassium acetate in distilled water, and the mixture is permitted to stand for a few days, occasionally agitating it, until complete solution has taken place. A tuft of glass wool is then moistened in distilled water and packed, not too tightly, in the apex of a funnel, and the thick liquid permitted to filter through it.

This is a good enclosing medium for any of the preparations stained with the anilin dyes, but is not suitable for carmine or hæmatoxylin preparations. For these, the following is used:

Hoyer's Fluid for Hæmatoxylin and Carmine Preparations. This is the same as the other, except that the solvent used is a concentrated solution of chloral hydrate in distilled water, to which 5 or 10 per cent. of pure glycerin has been added.

Specimens should not be transferred to either of these fluids direct from water but from strong glycerin. Preparations mounted in them are permanent, but greater safety to the mount is insured by running a ring of balsam of Fir or of asphaltum around the edge of the cover-glass.

MEASUREMENT OF THE MAGNIFYING POWER OF THE MICROSCOPE.

In the practical work of vegetable histology it is important that the student should know the magnifying power of his microscope, and be able readily to determine the dimensions of a microscopic object. Some directions regarding micrometry will therefore not be inappropriate here. We will suppose the student is provided with such a micrometer as has already been described. The whole length of the scale is one fifth of an inch, which is very nearly one-half of a centimeter, and, except where extreme accuracy is required, may be so regarded in practice. The one-fifth inch is first sub-divided into ten equal parts, and one of these, near the middle of the scale, also into ten equal parts, so that the larger divisions may be read as fiftieths of an inch or twentieths of a centimeter, and the smaller as five-hundredths of an inch or two-hundredths of a centimeter. Now, let us first determine the magnification with the low-power objective and low power eye-piece, and the draw-tube closed. There are various ways in which this can be done. We will first describe one which does not require the use of a camera lucida. By means of a drop of water fasten the micrometer to the centre of a glass slip, put it upon the stage, and focus upon the lines. Place the rule (a common foot rule will answer) parallel to the scale alongside the microscope and at a distance of ten inches from the eye. Look with both eyes, one directed at the micrometer scale through the tube of the microscope, and the other at the rule outside. After a little practice, the former scale may be seen superposed over the other and the magnification readily determined. For example, if it be found that one of the larger divisions on the micrometer scale correspond exactly with one inch on the rule, the magnification is just fifty diameters. In the same way the magnification may be determined for the combination when the draw-tube is pulled out one inch, two inches, etc.; and in like manner for any other combinations of objectives and eye-pieces.

A more accurate way, however, is to use a camera lucida, and project an image of the scale on paper at a distance of ten inches from the eye, or more strictly speaking, from the eye point of the microscope. If the Abbè form of camera lucida be used, it should be arranged so that the whole distance from the central aperture of the prism in a straight line to the axis of the mirror, which is supposed to stand at an angle of 45°, and from there perpendicularly to the drawing-table, is ten inches. Draw the image of the micrometer lines as projected on the paper and compare the spaces with those on the rule as before.

After having carefully determined the magnification of each optical combination, place the results in tabular form for future reference.

By projecting the image of an object upon that of the micrometer scale, previously drawn by means of the camera, its actual size may be accurately determined; or it may be determined, though less accurately, by placing the points of a compass in front of the microscope at a distance of ten inches from the eye, looking at the object through the microscope with one eye and at the compass points with the other, and adjusting the latter so as to accurately subtend the object, and then transferring its dimensions to paper. Knowing the magnifying power of the combination used and the apparent dimensions of the object, the actual dimensions of the latter may readily be determined.

In practice, however, it is much more convenient to read off the dimensions of the object by means of a micrometer scale, placed in the eye-piece. For this purpose detach the micrometer from the glass slide and insert it in the eye-piece in such a manner that it will rest upon the diaphragm between the two lenses. If necessary, screw out the eye-lens of the eye-piece a little, until the lines are accurately in focus. Let, now, any object whose dimensions have previously been measured with accuracy by one of the methods already described, be placed upon the stage and accurately focussed. If another accurately ruled micrometer is available as an object, so much the better. The lines of the eye-piece micrometer may now be seen superposed over the object on the stage, and the number of divisions of the former corresponding to the length of the object may be seen. Suppose, for example, the objective is known to be exactly one-five-hundredth of an inch in length, and that it subtends five of the small spaces of the eye-piece micrometer, each space, therefore, will have a value, with this optical combination and with this length of tube, of one fifth of one-five-hundredth, or one-twenty-five-hundredth of an inch. In like manner, the value of the spaces in the eye-piece scale may be determined for all the different combinations and for different tube-lengths.

The results should be placed in tabular form for easy reference and for habitual use.

DRAWING THE OBJECT.

No part of the student's work in vegetable histology has a higher disciplinary value than drawing the structures he sees under the microscope. The effort to represent a structure faithfully leads to close and accurate observation, one of the most important qualifications of a scientist. The student who practices it will see more with his microscope than one who does not, and he will also reach sounder conclusions regarding what he sees. Moreover, good drawings are a very necessary means of recording the results of observations if they are to have any permanent value. No record of microscopic work is complete without them. By mere verbal discription, however accurate, it is scarcely possible to convey to another a clear and vivid idea of a complicated microscopic structure. Nor can photography, useful as it is, take the place of the draughtsman's art. Success in conveying an accurate idea of a fact of structure often depends nearly as much upon leaving out unnecessary and confusing details, as upon presenting the essential things. But a photograph cannot discriminate. Moreover, a photograph represents clearly only what lies in a single visual plane. That which lies either above or below it is more or less indistinct, confused and confusing. Photography may and will perform an important part in microscopic research ; it may oftentimes very materially aid the draughtsman's art, but it can never take the place of it.

Very good and accurate drawings of microscopic objects may be made without the use of the camera lucida, an instrument which is capable at times of rendering important service, but which, if too much depended upon, tends more to foster slavish copying than to develop either artistic skill or the power of careful and accurate observation. The first efforts of the student at drawing had better, therefore, be undertaken without its aid. He should begin with simple structures, such as single cells, starch grains, etc., and after he has acquired a degree of skill, proceed to more complex structures. The apparent dimensions of an object may readily be transferred to paper by means of a pair of compasses in the manner already suggested. Further aid in getting the relative dimensions of different parts and in locating different points in the structure, may be obtained by a judicious use of the eye-piece micrometer. Of still greater advantage for the same purposes, however, is an eye-piece scale, ruled in equal squares with rather strong black lines and not too near together.

In using the camera lucida, it is of importance that the drawing-paper and the field of the microscope be nearly equally illuminated, otherwise the pencil-point and the object to be delineated cannot be seen with equal distinctness, and the lines of the structure, therefore, cannot be accurately followed. The outlines of the object had best be traced with a fine-pointed lead-pencil. Faber's or Hardtmuth's HHH drawing pencils are excellent for the purpose. The most convenient way to give the pencil a fine point is by means of a rather fine flat file. The tracing should be made on fine white cardboard, or on the smoother qualities of Whatman's drawing paper. The camera will seldom be used except to draw outlines and locate important points in the structure. The position in which it must be used makes the filling in of details and finishing by means of it too tedious and troublesome.

Drawings designed merely as a record of observations, or which are to be copied by the wood-engraver, may be finished in lead-pencil, but those which are to be copied by any of the photographic processes should be drawn with a pen in the blackest of black ink.

In his earlier attempts at drawing microscopic objects, the student would do well to use as models the admirable drawings found in Sach's Physiology of Plants and in Flückiger's Pharmacognosy.

GENERAL DIRECTIONS FOR MICROSCOPIC WORK.

1. Acquaint yourself thoroughly with the mechanism of the microscope you are to use.

2. Observe great care in the removing and putting on of objectives, so as not to drop them, for they are delicately constructed and liable to injury. The eye-pieces and eye-piece micrometer should also be handled with care.

3. Observe care in focussing, particularly when high powers are used, so as not to run the objective down against the slide and endanger either the cover-glass or the objective itself. Be sure also that you focus the microscope accurately, otherwise the structure of the object will not be distinctly seen.

4. Give due attention to the adjustment of the reflecting mirror, so as to secure the most favorable illumination of the object. Much of your success in

seing fine details of structure will depend upon the care exercised in this respect.

5. Bear in mind that many of the reagents used are corrosive and hence should not be brought into contact with the microscope. All the acids and iodine reagents will act upon brass-work, potassium hydrate will corrode glass, and alcohol will remove the lacquering from the stand.

6. All objects examined in liquids should be covered, not only to obviate the danger of injuring the objective, but to avoid the inevitable distortion of the image which a curved or uneven liquid surface produces.

7. Let cleanliness and care characterize all your work in the microscopical laboratory. Keep all your apparatus, slides, cover-glasses, etc., scrupulously clean. Do not touch the glasses of the objectives or eye-pieces with your fingers, for that would be to soil them and impair their optical performance. Whenever they need cleansing, breathe upon the glasses and wipe them either with a piece of perfectly clean and soft linen cloth, or with a piece of the thin, soft paper that is sold at dental supply-stores under the name of Japanese filter paper. A convenient way is to keep always at hand, in a place secure from dust, a quantity of this paper cut into suitable sizes. It is useful, also, for cleaning cover-glasses, slides, etc. If a fresh piece is used each time for cleaning an objective, there will be little danger of marring the polish of the front lens.

Keep the bottles containing reagents, staining fluids, etc., stopped when not in use, so as to exclude dust and prevent evaporation; and take especial care in using them not to introduce impurities into them.

8. In cutting sections, the razor or section-knife should always be very sharp, and for most purposes sections should be cut quite thin. Steadiness in cutting is secured by resting the wrists against the body. The knife should be given an oblique or sliding motion when drawn through the object. Quite hard tissues may be successfully cut if the sections are cut quite thin, but if the edge of the knife is allowed to run too deep, it is liable to be notched. Portions of thin structures like leaves, petals, etc., may readily be sectioned by placing them between pieces of Elder or Sunflower pith. Always clean the knife after cutting with it, and do not allow fragments of tissue to dry upon it. Sections of fresh tissues, or of those that have been preserved in any of the preservative fluids, should immediately be placed in liquid after cutting, to prevent air from getting into the cells.

9. In all your work with the microscope, proceed understandingly. Endeavor to know the reason for every test you are called upon to apply, and be careful in interpreting the results of each test. Do not rest satisfied until you thoroughly understand every tissue and structure given you for study.

10. It is excellent practice for the student to keep an accurate record in writing, and by means of drawings, of all the facts observed and the work done by him in the microscopical laboratory.

PART III.

VEGETABLE PHYSIOLOGY.

CHAPTER I.

SCOPE OF VEGETABLE PHYSIOLOGY.—PROPERTIES OF PROTOPLASM.

Vegetable Physiology treats of the functions of plants, or, in other words, of the way plants do their work, whether of vegetation or of reproduction. We have already touched upon this subject. In Parts I and II, where we described the mechanism of plants, we had, incidentally, more or less to say about the functions of parts and of various processes that go on in the plant. What was there said need not here be repeated, but it remains still to be explained how the plant, as a whole, performs its functions; how it absorbs, digests and circulates its food; how, through the organs it possesses, it makes use of the chemical and physical forces of nature to maintain its life, to build up its tissues and to reproduce its species.

All the activities which a plant exhibits are due to the wonderful substance, protoplasm, the appearance and structure of which have already been described. While the protoplasm lives the plant goes on building up its tissues, appropriating constituents of the soil and air to repair its wastes, and exhibiting all the profoundly interesting phenomena which belong to vegetable life; but when it dies, the intricate structure which it had built up, and of which it formed a part, falls rapidly into ruins, and the complex molecules constructed by its agency speedily decompose into simpler forms, and ultimately return to the mineral kingdom whence they came.

The properties or attributes of protoplasm, that is, those which serve to distinguish it from all those substances which we call "dead matter," are, according to Dr. Michael Foster, six in number, and may be stated as follows:

1. *Contractility*, or the power to change its form spontaneously, or by virtue of forces which reside within.

2. *Irritability*, or the power to respond to stimulus, and by reason of which a slight stimulus is capable of releasing a disproportionately large amount of energy.

3. *Respiration*, which consists essentially in taking in oxygen and giving out carbon dioxide.

4. *Destructive Metabolism*, or the changes which take place in the substance of the protoplasm itself, by virtue of which complex matters are continually being broken down into simpler forms, and finally into waste materials no longer of service to the plant.

5. *Assimilation*, or constructive metabolism; the power which living protoplasm possesses of taking in new materials and reconstructing old ones for the repair of its waste, or for increasing its substance.

6. *Reproduction*, or the power which protoplasm has of giving rise to new and similar organisms.

These properties not only sharply distinguish living from dead matter, but all living protoplasm, both animal and vegetable, possesses them in a greater or less degree. The power of contractility lies at the foundation of all spontaneous movements in animals and plants. Motion is a less conspicuous phenomenon in plants than in animals, but it is no less real. The higher plants show it in the slow movements of all young and growing organs, in the movements of the living matter within the cells, in the bending of organs toward or from the light, or toward or from the earth's centre, and, more conspicuously, in such movements as those of the upper internodes of climbing plants, of tendrils, of the leaves of some Mimosas, of Venus' Fly-trap, etc., but they are destitute of the power of locomotion, or of moving from place to place as the higher animals do. On the other hand, while some of the lower forms of animal life are fixed, some of the humblest of plants are conspicuously locomotive. Moreover, the modes of locomotion are, in many cases, identical with those observed among the simpler forms of animals. The Slime Moulds, for example, move from place to place by a slow, creeping process, accompanied by constant changes of form, precisely as in the case of the Amœba and kindred animal organisms, and Protococcus, in one stage of its life history, Pandorina and Volvox move by means of cilia the same as the Infusoria.

As regards irritability, that which plants exhibit is, of course, less in degree than that which, in the higher animals, rises into sensibility and sensation, but it can hardly be doubted, from the evidence before us, that it is the same in kind.

In animals this property is mainly concentrated in a highly specialized tissue called nerve tissue; hence its phenomena are strikingly evident, while in plants it is diffused through all the living tissues, and is in most cases but feebly manifested. But these differences do not hold when we come to compare the lowest forms of animal life with plants. In the lowest animals there are no nerve cells; the property of irritability is diffused, as in plants. The Dionæa, the Sundew and the Sensitive Plant exhibit a degree of irritability which equals, if it does not exceed, that shown by the lowest animal types. Moreover, every gradation is observed between the irritability of a tendril or a radicle and that shown by the higher animals. The conclusion therefore is irresistible, that the property is fundamentally the same in animals and plants—that irritability is an endowment of all living protaplasm.

Respiration, also, which consists essentially in taking in oxygen and throwing off carbon dioxide, is much less evident in plants than it is in animals, though certainly it is no less real. It is a less noticeable phenomenon in plants, partly because, being less active organisms, they waste less rapidly than animals do, and the respiratory process is consequently slower; partly, because it is not carried on by means of a special breathing apparatus, as it is in those animals with which we are best acquainted, but more, perhaps, because in ordinary green plants the process is masked in the daytime by the assimilative one, which goes on at the same time. In the latter process, carbon dioxide is consumed as food, in quantities larger than that thrown off in respiration; and the amount of oxygen which is consumed in respiration is more than counterbalanced by that set free in the work of assimilation. For this reason, it is difficult, in the daytime, to demonstrate the respiratory process in green plants. But at night, the assimilation of carbon dioxide is suspended, while respiration, which goes on continuously, can readily be discovered by appropriate experiment.

The fact of respiration in plants has also been demonstrated by experiments on fungi and other plants destitute of chlorophyll, and which, therefore, cannot utilize carbon dioxide as food. Here the inhalation of oxygen and exhalation of carbon dioxide is found to go on continuously, as in animals.

Both classes of organisms are also in substantial agreement as regards destructive metabolism. In both, the energy which results in the various phenomena of life is derived from the breaking down of complex into simpler matters by processes of oxidation. In both, complex compounds with much potential energy become simpler compounds with less potential energy, and the difference becomes kinetic or actual energy in the form of heat, electricity and mechanical motion, giving rise to the various activities of the organism. Here lies the significance of the respiratory process. In this transfer of matter from a higher to a lower potential, oxygen is consumed, and gaseous carbon dioxide escapes as one of the products of the change. The organism is therefore in many respects comparable to an engine in which the latent energy of the fuel is converted into work, while during the process, the wood or coal passes into carbon dioxide and water which are no longer available as sources of energy.

The products of metabolism are not always the same in the plant as in the animal, but the differences are only such as can readily be accounted for by differences of habit; indeed, they are scarcely greater than those existing between animals of widely different habits. There are, in fact, few vegetable products whose analogue is not somewhere found in the animal kingdom.

The divergence between plants and animals is perhaps widest in the matter of assimilation or constructive metabolism. Green plants have a power not possessed by most animals, of raising mineral matter into comparatively complex organic compounds. Thus they derive their sustenance directly from the inorganic world. From the elements of water and carbon dioxide they form a carbohydrate, and then, by bringing this into other combinations, or causing it to pass through other chemical changes, they use it to build up their tissues. This the animal cannot do;

he is dependent for his sustenance on already organized matter. He is, in fact, indebted for his very existence to the constructive work of the plant. But this distinction, which separates with apparent sharpness the chlorophyll plant from the ordinary animal, is not universal. Most parasitic and saprophytic plants, being destitute of chlorophyll, are, like the animal, dependent on organic food materials for their existence. Moreover, chlorophyll plants are not green throughout; a part of the cells contain green coloring matter, but another part, often the larger part of the plant, contain none whatever. These cannot assimilate their own food-materials; they are dependent for their sustenance on the organic matters elaborated by the green cells. In the way they are nourished they agree essentially with animals, yet their origin is the same as that of the chlorophyll-cells with which they are associated; both are products of cell-division from the original germ-cell in the embryo-sac.

Lastly, as regards the modes of reproduction. Here again the parallelism between animals and plants is very complete and striking. Among both are found organisms which reproduce by cell division, in its various modifications of budding, fission and internal cell-formation. Many animals bud and branch like plants, and some of these approach so nearly to plants in appearance and habit of growth that it requires careful observation to distinguish them. The lowest animals, like the lowest plants, reproduce by cell division only; organisms a little higher in the scale, in each kingdom, reproduce by conjugation or the union of two similar cells; and the highest animals, as well as the highest plants, reproduce by fertilization, or the union of two different cells.

Plants and animals, therefore, resemble each other fundamentally; the protoplasm which constitutes the physical basis of life of both has in both the same essential properties. We must regard plants and animals as two branches of a common trunk. The first living being that made its appearance on our globe was probably neither distinctly plant nor animal, but a bit of undifferentiated protoplasm. From such a form, for a common trunk, have diverged the two great branches of the tree of life, each of which, by countless ages of growth, and repeated branching, has given rise to an innumerable and richly varied series of forms.

CHAPTER II.

CONSTITUENTS OF PLANTS.—FOOD OF PLANTS.—HOW THE FOOD IS ABSORBED.—ASCENT OF THE SAP.—GASES IN PLANTS.

Constituents of Plants. By dessicating a plant at a temperature too low to cause chemical decomposition, we find it loses greatly in weight, owing to the evaporation of the free water, which always forms a large part of the substance of the living plant. The amount, however, varies greatly in different plants, and in different portions of the same plant. In aquatics, it often reaches 95 per cent., while in the wood of some trees, it may fall as low as 20 per cent. The average for herbaceous plants is probably not far from 75 per cent. It pervades all parts of the organism, the protoplasm, the cell-walls, and, at times, even the intercellular spaces. Protoplasm, as we have seen, has the power of absorbing it in very large proportion. By this means the cell-walls are kept distended, so that even plants which are composed very largely of thin-walled cells are turgid and resistant. This avidity of protoplasm for water has, as will presently be shown, much to do with the circulation of the sap, and, consequently, with the nutrition of the plant. Water is also the best solvent in nature, and as such, plays a very important part in the life of the plant. By virtue of this property, it is the means by which solid matters are taken into the interior to serve as food. It is the agent by which they are conveyed to the appropriate organs to be digested, and it is the means by which, when this has been accomplished, they are carried to the various parts of the plant, where they are required for the renewal of wastes, for the construction of new tissues, or for storage against future requirements. It is also one of the most important of the raw materials made use of by the plant as food.

If the dessicated plant now be burned, the larger portion will pass off in the form of gases, consisting of watery vapor, carbon dioxide, etc., while another portion, varying in amount according to the nature of the plant and its age, will be left behind as ash. If the combustible portion be analyzed, it will be found to contain the elements Carbon, Oxygen, Hydrogen and Nitrogen, and an analysis of the ash will show it to consist of Potassium, Phosphorus, Sulphur, Calcium, Magnesium, and usually, also, other elements. Among these constituents we must distinguish those which are essential, those which are of minor importance, and those which are merely accidental. Those found to be essential to the lives of all plants are Carbon, Oxygen, Hydrogen, Nitrogen, Sulphur, Potassium and Phosphorus. The first three are the constituents of all carbohydrates, as starch, cellulose, sugar, etc.; in addition to these, protoplasm contains, as essential constituents, nitrogen and sulphur. Potassium and phosphorus, though not properly constituents of protoplasm, are always found in relation to it, and closely associated with the activities of the plant. The former appears to be essential to the formation of starch, and to be concerned, also, in its transfer from one part of the plant to another, while the latter, though its functions are not well understood, enters as an essential constituent into some of the important organic compounds of the plant, as, for example, nuclein and chlorophyll. In the form of the phosphates, it also promotes the process of metabolism in the cell, and probably by rendering albuminoid matters more soluble, aids the transfer of these important substances.

Additional elements essential to the lives of some plants are Iron, and, perhaps, Chlorine. Iron is found in minute quantities in nearly all plants, but is really essential only to the chlorophyll-bearing ones. Plants deprived of iron do not develop chlorophyll, but appear as if bleached. It is still somewhat uncertain whether chlorine is really essential to any plant, but some experiments appear to prove that it is necessary to Buckwheat and a few other plants.

The elements of minor importance to the plant are Calcium, Magnesium, Sodium and Silicon. It has been found by experiment that plants cease to thrive after a time when completely deprived of calcium salts. The reason of this is not fully known. Both calcium and magnesium are of value to the plant, however, from the fact that their phosphates, nitrates and sulphates are important sources of sulphur, nitrogen and phosphorus. They are probably useful, also, in fixing and rendering harmless certain acids set free or formed by the activities of the plant. Sodium, though present in all plants, and very abundant in some, has not been ascertained to have any very important use. It has been found, however, that it may, to a very limited extent, replace potassium in some plants. Silicon, which occurs in the form of silica, is widely distributed plant constituent, and in some cases is very abundant, as in the Diatoms, Equisetums, and many Grasses, but it appears to have but little physiological importance. Its chief service seems to be mechanical, affording strength or protection to the organ which secretes it.

Among the accidental constituents of the ash of plants occur Alumnium, Manganese, Fluorine, Bromine, Iodine, Lithium, Barium, Strontium, Copper, Cobalt, Nickel, Tin, Zinc, and several others, but most of them, except the first five, are of rare occurrence, and, when present, exist in very small quantities.

Food of Plants.—The young plant when it begins to germinate from the seed, is still practically dependent on the food-stores laid up for it by the parent plant. It is incapable, that is, of deriving its sustenance directly from the soil. Its cells, besides containing protoplasm, are heavily charged with nourishing matters, such as starch, sugar, oil and reserve proteids which the protoplasm makes use of for the purposes of growth. It may also, as we have seen, have an outside supply laid up for it in the form of endosperm or perisperm, which serves the same purpose. When the seed is placed in favorable conditions, as when lodged in moist, warm soil, the dormant protoplasm of the embryo becomes active, water is greedily absorbed by it from the outside, the stores of reserve-materials are rapidly changed by the acid of ferments present, into soluble forms, as starch and oils into dextrin and sugar, and these are applied to the formation of new cells. As the plantlet increases in size, sending its radicle into the ground, and its plumule, and perhaps also its cotyledons, into the air, its food-stores diminish *pari passu* and are finally exhausted, and the plant now becomes entirely dependent on the soil and air for its sustenance. In the meantime, it has developed rootlets and numerous root-hairs as absorbent organs, and expanded to the air a few green leaves which are to assimilate the absorbed materials. It is evident that its food must now be of a different nature. It must, of course, take in all the elements mentioned above as essential constituents, and that it may thrive to the best advantage, it must have also those elements which were designated as of minor importance. But it no longer takes them in such complex forms as those in which they were stored in the seed. On the other hand, none of them, save oxygen, can the plant utilize in the elementary form; and even its consumption belongs largely, if not wholly, to the respiratory rather than to the assimilative process. They are absorbed in the form of inorganic compounds. A considerable portion, even of the oxygen, is obtained from water and from various salts absorbed by the plant. The carbon is derived from carbon dioxide; the hydrogen, mainly, at least, from water; most of the nitrogen from ammonia, ammonium salts and the nitrates; the sulphur from the sulphates; the phosphorus from the phosphates; chlorine from the chlorides; potassium from the phosphate, chloride, sulphate and probably also the silicate; sodium, mainly from the chloride, and calcium, magnesium and iron from the sulphates, carbonates, nitrates and phosphates of these elements.

The carbon dioxide, made use of by the plant as food, is absorbed from the air. Oxygen is taken by land plants partly from the air, and partly from solution in the water that permeates the soil. The mineral salts required by plants exist in minute quantities in the dust of the atmosphere, yet in proportion large enough to supply the needs of epiphytes; but they occur in still greater abundance in most soils, which is the source whence the great majority of plants obtain their supplies. Besides these inorganic salts there are in most soils various decomposing organic matters, which many plants are able to appropriate; but that these are not really essential to plant life, is shown not only by the fact that Cactus plants and House-leeks grow on bare rocks, or in arid sands, but also by experiments like the following: If the root of a germinating Bean be placed in solution containing, in 1,000 parts of water, about two parts of the following compounds, potassium nitrate, iron phosphate and calcium sulphate, and its leaves be exposed to the sunlight and air, care of course being taken that a suitable temperature be maintained, it will grow nearly, if not quite, as well as if planted in the soil.

Absorption of Food. Carbon dioxide, or at least that portion of it which is utilized as food, reaches the interior of the plant through the leaves or other chlorophyll-bearing parts. Other food-materials are also to some extent absorbed by leaves. Young branches, glandular and other hairs, aerial roots, and to a limited extent also mature stems, particularly those of herbaceous plants, may act as absorbing organs. Air plants must obtain their entire supply of food in this way. Nutritive material may, in fact, be absorbed by the entire surface of the plant, as is the case with many aquatics. But the great majority of the higher plants obtain their saline food-materials in aqueous solution, chiefly from the soil, by means of the innumerable delicate roots and root-hairs with which they are provided. They are conveyed, by a process presently to be described, through the membranous cell-walls of these organs, and thus find their way into the interior of the plant.

To understand this process, it is important that the student first clearly comprehend the laws of liquid diffusion and osmose. It is well known that if two miscible liquids, for example, alcohol and water, be placed in contact with each other carefully, so as to cause as little commingling as possible, they will, nevertheless, after the lapse of a little time, be found to be completely mixed, so that the mass has exactly the same composition throughout. This is due partly to molecular motion, and partly to the attraction which the molecules of the different liquids have for each other. The phenomenon is called diffusion. If a thin animal or vegetable membrane be stretched between two different liquids, both of which are capable of wetting the membrane, the same thing will take place, only somewhat more rapidly. Currents will move to and fro through the membrane, until the composition of the liquids on either side becomes the same. In case both liquids are capable of wetting the membrane, but one is denser than the other, usually the stronger current will be toward the denser liquid, and on that side of the membrane the level of the liquid will rise; if, for example, pure water be on one side and a solution of sugar in water be on the other, the stronger current will be toward the sugar solution. But the general rule has some exceptions; for instance, if water be on one side and alcohol on the other, the stronger current will be from the water toward the alcohol, although the former is the denser liquid. It is an important fact also that, if on one side be placed an aqueous solution of gum, albumen or other colloidal substance, and on the other an aqueous solution of some crystalline substance, the latter will pass through to the colloidal side with great facility, while but little, if any, of the colloid will traverse the membrane in the opposite direction. To phenomena like these the term *osmose* is applied. The membrane contains no visible pores, even though viewed with the highest powers of the microscope. How, then, is the phenomenon to be accounted for? There is reason to believe that organic membranes consist of a minute network of solid organic particles or threads, the meshes of which are filled with constituent water, or water which is held by an attractive force so strong that it cannot be expelled without destruction of the membrane, and yet which still retains essentially the properties of water. Such a membrane would permit the diffusion through it of any liquids capable of mixing with water, very much as though only a film of water were stretched between the liquids. There would, however, be this difference: the interchange would be somewhat impeded by the network, and it is evident also that the denser liquid, other things being equal, would be more impeded than the less dense one. We are thus able to explain the phenomena of osmose.

Now, the cell-walls of root-hairs and root-cells are organic membranes which separate a colloidal solution within the cells from a saline solution without, namely, the water that, with its dissolved mineral matters, permeates the soil. An interchange of liquids therefore takes place, and much the stronger current is toward the interior of the cells.

The imbibition of liquid through the roots is aided in various ways: (1) By the branching of the root into numerous fine divisions which develop near their tips great numbers of root-hairs. (2) By the fact that the root-hairs are in intimate contact with numerous earth particles, and even grow fast to them. (3) Each earth particle, except when the soil is excessively dry, is enveloped in a closely adhering film of water, and as each particle is in contact with adjacent ones, the whole virtually forms a complicated network of capillary tubes through which water is drawn from a distance, in proportion as that adjacent to the root-hairs is absorbed. (4) The liquid of the exosmotic, or lesser current, from the interior of the cells outward, is of indirect service, on account of its acid properties, in bringing mineral matters into solution, which are afterward absorbed by the plant. (5) The process of imbibition is also greatly aided by the avidity for water which is possessed by the protoplasm of the young and growing root cells.

The Ascent of the Sap. The laws of diffusion and osmose also help us to understand the ascent of the sap. For the same reason that the exterior root-cells absorb water from the soil, those adjacent to them absorb from these, which, in turn, yield up a portion of their contents to others still farther interior, and so the sap is passed on from cell to cell until finally it reaches the most remote parts of the plant. The process is, however, greatly aided by what is called root-pressure. This is due to the fact that the root-cells continue to absorb, even after they are no longer able to hold any additional liquid, and the pressure exerted by their turgid walls forces a part of the sap-contents through the inner walls into adjacent cells; that is, it filters under pressure from cell to cell. The fact that the liquid is forced inward, rather than outward, into the soil, may be accounted for by supposing that the interior wall, or face of the cell, has a structure somewhat different from that of the exterior one. This pressure, in the growing season, makes itself felt in the remotest part of the plant. The exudation of water in drops from the water-pores of certain leaves, is due to this cause. For this reason, also, plants often bleed copiously when wounded. The amount of pressure of this kind, exerted by a plant, may be measured, and has been found in some instances to considerably exceed one atmosphere, or fifteen pounds to the square inch; but it varies greatly in different plants, and at different times in the same plant.

The ascent of the sap has been found to take place very largely, though not exclusively, along the fibro-vascular bundles. In the stems of trees it is chiefly along the sap-wood. It must not be understood, however, that these tissues are in any proper sense circulatory organs, such as we find in the higher animals. No such organs exist in plants. While there is a distinctly traceable upward movement of the crude sap along certain tissues, no such distinct downward movement of the elaborated sap can be observed, but there occur chiefly the slow movements of diffusion. Moreover, the ascent of the sap is not mainly through long tubes, but from cell to cell, from fiber to fiber, from duct to duct.

It is evident that all movements of sap would soon cease on account of the establishment of an equilibrium of fluids in the cells, just as the osmosis of any two liquids through a membrane ceases as soon as the liquids on either side of the membrane cease to differ in composition, were there not in the growing plant disturbing causes constantly coming into play. These causes are various.

One is *the evaporation of water from the plant*. This takes place very largely from the leaves. It is greatly facilitated by the enormous surface which these organs expose to the sunlight and air, but it is also promoted by their structure. The numerous stomata and the loose arrangement of the cells of the interior of the leaf, permitting within it a free circulation of air, greatly facilitate the process. The leaf-cells, thus losing a portion of their water by evaporation, are able to take up more from the cells below, and so the ascent of the sap continues.

Another cause is *the formation of new cells*. This is constantly taking place in various parts of the plant during the season of growth, and, as the protoplasm of each young and growing cell has a great avidity for water, it absorbs it greedily from adjacent cells, and these from others, and so on.

Every chemical change, also, and these changes are all the time taking place in the living plant, more or less disturbs the equilibrium of fluids, and so promotes their movement. If a new soluble compound be formed, for instance in the leaf, it tends to diffuse to all other portions of the plant, until equally distributed. The change of substances of less density to those of greater density, of crystallizable to colloid bodies, of liquids to solids, or of solids to liquids, will each and all give rise to movements of diffusion. It is probable, also, that the mechanical movements of branches and leaves by the wind may be of considerable service in promoting the circulation of fluids in the plant.

Gases in the Plant. The most important of the gases found in the plant are carbon dioxide, oxygen, nitrogen and watery vapor. These exist either in solution in the cell-sap, or free in the intercellular spaces, and in the cavities of the vascular tissues.

Carbon dioxide, which, as we have seen, is of extreme importance to the plant as food, being the chief if not the only source of the carbon which forms nearly one-half of the dry weight of every plant, is absorbed not only from the air directly by the green cells in the assimilative process, but some finds its way to the interior of the plant in solution in the water absorbed by the roots. It is also produced in the process of respiration, and given off as waste matter by all the living cells throughout the body of the plant.

Oxygen is also obtained by the plant from the air direct, and is taken up in solution by the roots, but it is also set free in large quantities by the assimilative processes in the green parts of the plant.

Nitrogen, which forms a normal constituent of the air, is found both free and in solution in all parts of the plant, being absorbed along with other components of the air, both directly and in aqueous solution through the roots, but it does not appear to play any important part in the vital processes of the plant.

Watery vapor exists in the cavities of the plant in larger or smaller proportion, and is exhaled in abundance from the stomata.

In the living plant these gases are never absolutely quiescent, or in a state of perfect equilibrium. Owing to the chemical activity of the cells, to the evaporation constantly going on at the surface, to the varying temperature of the air, causing expansion or contraction of the gaseous contents of the plant, and to the mechanical agitation caused by the wind moving among the leaves and branches, the gases in the plant are in constant movement, though the movements are by no means regular or uniform.

One interesting effect due to the presence of gases in the plant is seen in the bleeding of trees when wounded in early spring. At this season of the year, before the buds begin to unfold, and there are few stomata or other escapes for the pent up gases, and when, at the same time the tissues are gorged with sap, if the tree be wounded, the expansion of the gases on the interior, caused by the heat of the day, forces out a portion of the sap. In some trees, as the Maple, the flow is so copious and so sweet that it is profitably employed as a source of sugar.

In cases of bleeding due to this cause, the sap-flow usually ceases at night, or when the temperature is suddenly lowered during the day, owing to the contraction of the gases in the tissues of the stem. After the leaves unfold, the flow also ceases, owing partly to the fact that with the season's advance, such sudden and considerable changes of temperature have ceased, partly to the evaporation which now takes place from the leaves, and partly to the avidity with which the protoplasm of the young cells in the growing twigs and leaves absorb the liquids from below.

PRACTICAL EXERCISES.

1. Take a wide-mouthed bottle of a half pint capacity or more, and fill it half full of barley; pour in a quantity of water barely sufficient to completely cover the grain; in the cork stopper bore a hole of such size that the tube of a thermometer will nicely fit it; insert the cork and thermometer in such a manner that the bulb of the latter will be buried in the grain and the cork will fit loosely in the neck of the bottle; set the vessel away in a moderately warm place for twenty-four hours and then observe. It will be found that the water has been partly or wholly absorbed, and the grains have swollen so as to occupy much more room in the vessel than at first. Moreover, on examining the thermometer and comparing the temperature indicated by it with that of the outside air, it will be found that the heat has been developed in the process.

Continue the experiment, keeping the grain moist but not submerged in the water. The radicles will soon be observed to protrude through the ruptured coats of the grains. Now compare the taste of one of the grains with that of one which has not been soaked. Both will have a farinaceous taste, but the former will be perceptibly sweeter. Let the germination of the remainder proceed until the protruded radicles are fully two-thirds the length of the grain, and then again compare the taste with that of an unsoaked grain. A more decided difference will now be perceived, the sweet taste of the germinating grain being still more evident, while the farinaceous taste has almost, if not entirely, disappeared.

Make a thin section of an unsoaked grain and treat it with a drop of iodine solution. It will immediately turn a dark violet color, showing that starch is present in abundance. Test in the same way a section of a germinated grain and if the germination has proceeded far enough, only a yellowish-brown color will be produced, showing that the starch has disappeared. It has been converted into sugar as could readily be proved by applying Fehling's test. If at this stage of germination the grain be poured out of the bottle and rapidly dried at a temperature sufficiently high to destroy the vitality of the germ without carbonizing the grain, say a temperature of about 160° F., the result will be malt, a substance largely used in medicine and in the manufacture of malted liquors.

If, however, the growth of the grain be longer continued, the sweet taste at first developed will gradually disappear, the sugar first formed from the starch being now used up in the formation of new tissues.

2. Some idea of the force with which germinating seeds imbibe water may be obtained by filling a tumbler partly full of beans, pouring on water enough to completely fill the interspaces, covering the beans with a sheet-iron or board disc, cut to loosely fit the inside of the tumbler, and placing on this an iron or lead weight. The position of the disc should now be accurately noted by making a mark on the outside of the glass. After a few hours, the weight, even though many times heavier than the weight of the beans, will be found to be raised.

3. Try the following experiment in osmose. Obtain a glass tube six or eight inches long, having a diameter of about half an inch, and having its ends cut off square. Soften one end in a Bunsen flame, and having whittled a stick into conical form, run the point into the heated end of the tube and rotate it so as to render the edge of the tube somewhat flaring. When this end of the tube is sufficiently cool, tie securely over it an imperforate piece of bladder, in such a manner as to form a sac rather large in diameter as compared with the thickness of the tube. Pour into the open end of the tube a rather thick solution of sugar until the liquid fills the bladder and stands an inch or so high in the tube. Then immerse the apparatus in a glass vessel containing about the same amount of pure water and fasten the tube in an upright position so that the liquid within it will stand at about the same level as that outside. After some hours, observe that the liquid within the tube has increased in volume and now stands at a considerably higher level than at the beginning of the experiment. Observe also that the liquid outside in the glass has a sweetish taste.

Now reverse the experiment by placing pure water in the bladder and about an equal quantity of sugar solution in the glass, and observe carefully the result.

Again vary the experiment by substituting for the solution of sugar in the first experiment, one of gelatin made just sufficiently dilute so that it will not set on cooling. After the lapse of twenty-four hours test the water in which the tube and bladder have been immersed, for gelatin, by dropping into it a solution made by dissolving a few grains of tannin in a little hot water. If any of the gelatin has passed through the membrane and mingled with the exterior liquid, a curdy white precipitate will immediately appear. Observe also whether the level of the liquid in the tube has risen or fallen.

4. Study root-pressure by means of the following experiment: Cut off the stem of some thriftily growing woody plant, as for example that of the Grapevine, a few inches above the ground; slip over the stump one end of a short piece of rubber tubing and secure it firmly by means of a string; into the other fasten the open end of a glass tube bent as shown in Fig. 463 and closed at the opposite end. The tube should have a little mercury in the lower bend, and should be fastened in the position shown in the figure. The closed arm of the tube should, for convenience, be about ten inches long. Great care should be taken that the joints are perfectly tight. Note carefully the level of

the mercury in the tube at the beginning of the experiment. After a time, the water forced out of the stem will begin to drive the mercury up the long arm of the tube against the pressure of the atmosphere, and, since the volume of the air will be inversely as the pressure, the extent of the root-pressure may readily be determined.

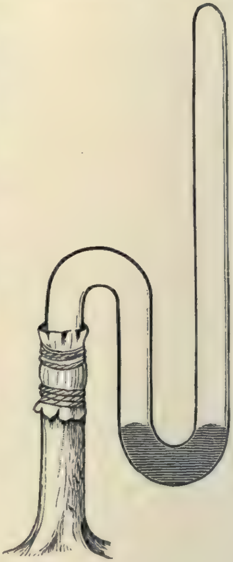


FIG. 463.

5. Cut off the stem of a thriftily growing woody plant which is in full leaf, and immediately plunge the cut end into an aqueous solution of aniline blue. After two or three hours remove the stem from the staining fluid, and immediately cut transverse sections of it at various heights and observe how high the staining material has ascended and along what tissues. The juice of Poke-berries or a decoction of Brazil-wood may be used instead of aniline-blue with good results.

6. Wipe the inside of a bell-jar perfectly clean; place underneath it a growing plant and expose it to the light. Drops of water will soon gather on the inner surface of the jar and after a time will run down its sides.

Vary the experiment as follows: Cut off a leafy branch of some thriftily growing plant and immediately immerse the cut end in water contained in a rather tall and narrow glass jar; stop the mouth of the tube so as to prevent evaporation from the surface of the liquid. Mark on the outside of the jar the height at which the water stands on the interior at the beginning of the experiment, and expose the leaves to the sunlight. After a few hours, it will be found that the level of the liquid is very perceptibly lowered. By measuring the quantity of the water at the beginning of the experiment, and then again at its close, and noting accurately the time, the rate at which evaporation has taken place may readily be determined.

7. Cut off two twigs of some woody plant that has large leaves, and is growing vigorously. Let one of them be cut rather high up where the tissues are young and little lignified, and the other lower down where they are considerably lignified. Immerse the cut ends of both in water immediately. The former will wither sooner than the latter. Why?

8. Select two twigs, both from the same plant, which are of about equal size and possess about the same number of healthy leaves. Cut one of them off in the air, immediately immerse the cut end in water and let it remain in sufficient water until it has withered away; but arrange to cut the other off under water, and take care not to expose the cut surface to the air, but keep it immersed in water; every day cut off a thin piece from the immersed end without removing it from the water. Continue this until the leaves begin to wither. It will be found that the twig thus treated will survive much longer than the other. What is the reason?

CHAPTER III.

ASSIMILATION OF FOOD.—DISTRIBUTION AND STORAGE OF FOOD MATERIALS.—DESTRUCTIVE METABOLISM.—INFLUENCE OF TEMPERATURE ON THE LIFE OF THE PLANT.—INFLUENCE OF LIGHT ON THE LIFE OF THE PLANT.—PARASITES AND SAPROPHYTES.—PRACTICAL EXERCISES.

Assimilation of Food. It is, as has already been seen, one of the functions of living organisms to take in materials different from themselves, change them in chemical composition, and appropriate them to their uses. Some require that the materials be in a complex form, others are able to make use of those which are relatively simple. Organic beings cannot create energy; they can only dispense or apply to serviceable ends that which is supplied to them. Animals and chlorophylless plants are dependent for their vitality on the energy supplied by the oxidation of the complex food-materials which they take into their bodies, but chlorophyll plants are able to do an additional work. They can make use of the energy of the sun's rays in constructive work. By their aid they construct, from mineral constituents of the earth and air, complex organic matter, which is afterward used, partly by themselves and partly by other plants and animals, in carrying on their vital processes and building up organic tissues. The utilization of the sun's rays by the plant is accomplished by the agency of the chlorophyll. This green coloring matter, this verdure which in grass and leaf gives the chief glory to the summer landscape, has other uses than merely to please the eye of man. By means of it, organic beings are able to draw perpetual supplies of power from the sun; without it, it is difficult to conceive how life, save possibly in some of its lowest forms, could exist upon the earth.

The precise function of chlorophyll is to apply the energy of the sun's rays to the production of some form of carbo-hydrate, which is not starch, but some related body. This, by immediate combination with the nitrogen and sulphur taken up in the form of salts by the plant, forms proteid matter. The exact composition of this carbo-hydrate, we do not know, nor do we know precisely the process of its formation, or of the production of proteid matter from it, but we know it is made from carbon-dioxide and water.

Since the molecules of carbon-dioxide and water contain more oxygen than is required in the construction of the molecule of a carbo-hydrate, a portion of it escapes from the plant as free oxygen. Suppose, for example, the carbo-hydrate be represented by the formula $C_6H_{10}O_5$ we may express the formation of its molecule by the following equation: $6CO_2+5H_2O=C_6H_{10}O_5+6O_2$. In this case, it will be seen, six molecules of oxygen, or as much as is contained in the carbon dioxide used, become free, and it is evident that an amount equivalent to this would be set free in any case, whatever the carbo-hydrate formed. The equation, however, must not be taken to express the process which actually takes place, for the reactions are probably much more complicated than this would imply.

The deoxidizing power which the chlorophyll plant possesses is of the highest significance, so far as the maintenance of life is concerned. Animals are continual consumers of oxygen and generators of carbon-dioxide, and if there were no means of setting free again the oxygen they are continually bringing into combination, the atmosphere would soon become poisonous and unfit to sustain animal life; but plants, by feeding upon the carbon-dioxide which animals exhale, and restoring the oxygen which they consume, maintain the atmosphere at nearly a constant composition, and the balance of life is kept in equilibrium.

It was formerly supposed that the starch granules found in the interior of the chlorophyll-bodies were the direct result of the assimilation of carbon-dioxide and water, but the investigations of Strasburger and others clearly prove that this is not the case. They are formed from protoplasm, the latter substance being broken down by the agency of the chlorophyll into this and other products. It is probable also that that formed by amyoplasts in chlorophylless cells is also produced from proteid matter. Its formation, therefore, might be regarded as belonging rather to the destructive than to the constructive processes of the plant; the breaking down, however, is only preparatory to reconstruction; for starch is one of the most important of the reserve food-materials of the plant. Stored away in various parts of the vegetable structure, it is so much capital which the plant may draw upon in case of need, to build up new tissues, to repair losses and wastes, or to carry on the exhaustive work of reproduction.

The power to utilize starch for the building up of protoplasm is not the exclusive property of the green cells, as is that of the first formation of carbo-hydrate. but it is possessed to a greater or less extent by all the living cells of the plant. Tissue construction from starch is also not dependent upon light. A potato will sprout in a dark cellar, and the sprouts will continue to grow until they have exhausted all the reserve food-materials in the tuber ; but when this is done they die, for they cannot, without the aid of the sun's radiant energy, construct new materials ; no new carbo-hydrate can be formed, as we have seen, in the absence of light.

In addition to the assimilative powers already described, all plants are able to reconstruct living out of dead protoplasm. Fungi appropriate, along with other matters, the dead proteids of the decaying organic substances on which they feed. The Sarracenia and Sundew catch and destroy insects, and nourish themselves by the proteids thus obtained. The benefits derived from the use of manures depends, partly at least, on this power possessed by living cells. Every plant also lays by, for its future needs, certain reserve stores of proteid ; these it re-vivifies as occasion requires, and there are also formed in the plant certain lower forms of nitrogenous organic matters, such as asparagin, leucin, etc., which it is able to convert into living protoplasm.

Such, in brief, is the constructive work of the plant.

The Distribution and Storage of Reserve-Materials. Starch, in its ordinary form, is insoluble in cold water, and protoplasm, as we have seen, is a colloidal substance, and therefore difficultly diffusible. Both must consequently undergo change and pass into other forms, in order to be distributed to the various parts of the plant, where they are required. The starch granules formed in the chlorophyll-bodies under the influence of light, undergo solution in darkness, and disappear. Probably this solvent process is in continual operation during the day, but, owing to the fact that the formation is more rapid than the solution, the latter process cannot be directly observed. In undergoing solution, the starch is changed into sugar, which, in its various forms, is a highly diffusible substance. It may thus be conveyed to parts very remote from its place of formation. The transformation is brought about by the agency of diastase, or some similar unorganized ferment.

In the form of sugar, it may be conveyed to growing parts and applied to the construction of tissues, or it may be carried to various parts of the plant, as seeds, tubers, etc., and laid by as reserve material. In this case it is sometimes stored as sugar, for example, in the Sugar Beet; sometimes it is laid up in the form of cellulose, as in the Ivory Palm and Nux Vomica seed; and sometimes it first goes to the formation of protoplasm, and then of reserve proteid material, such as aleurone grains, etc.; but it is more commonly either re-converted into starch, or else stored in the form of fixed oil.

When starch and oil are to be conveyed from the tissues where they are held in reserve to growing parts, they are again brought into solution in the form of sugar, or some other soluble carbo-hydrate, by the agency of an unorganized ferment.

The transfer of proteid materials also takes place by their conversion into compounds which are more readily diffusible, such for instance as the amides, asparagin, glutamin, leucin, etc. Doubtless their transfer, both to the place of storage and from it, to the parts where they are required for use, is accomplished chiefly in this way.

Destructive Metabolism. At the same time that the constructive work of the plant goes on, there proceeds also a work of disintegration and destruction. In the economy of the organism, life and death go hand in hand. The oxidation and consequent breaking down of certain organized structures is a source of energy which the plant uses in the work of construction. If the constructive processes are in excess of the destructive ones, there is growth; if the latter are in excess of the former, the whole organism soon dies. Every plant has its period of growth, when the life-forces are in the ascendant; its period of maturity, when repair and waste are nearly evenly balanced; and its period of decline, when the destructive forces gain the ascendancy.

The highly organized structures that constitute the tissues of the plant, do not return at once to the mineral kingdom from which they were derived, but their return is by successive steps and by various roads. The products of destructive metabolism are, therefore, numerous and varied. They range in complexity from bodies like the alkaloids to those as simple as carbon-dioxide and water. It is not easy to draw the line between products of metabolism which are still serviceable to the plant, and those which are not. Some products of the disintegration of protoplasm, being of the utmost nutritive value, are hardly to be classed as products of destructive metabolism. This is the case with starch and other carbo-hydrates, fixed oils, and the amides. But here we must class the organic acids, for, though some of them are certainly to some extent nutritive, they are on the whole much less valuable. In the ripening of acid fruits, some of the acids are apparently converted into sugar, a nutritive carbo-hydrate; some do a service in bringing mineral matters of the soil into solution, so that it may be taken up by the root-hairs, and some are of use in decomposing mineral salts. The glucosides, which are probably produced by the breaking down of proteid matter, have not been proved to possess nutritive value beyond being a source of sugar. When decomposed by ferments or organic acids, the glucose they yield may, of course, be applied to nutritive uses. The alkaloids are probably purely waste products, as are also the resins and volatile oils, so far at least as nutritive purposes are concerned; they may, however, as has already been suggested, be of some slight use, by affording protection against animals and destructive fungi, or, in the case of volatile oils, they may indirectly aid in cross-fertilization.

While in a general way the products of destructive change resemble each other in different plants, in fact, in many cases are identical, this is not always the case. There are numerous instances where a compound is produced by a single species or genus, and is not found elsewhere. The valuable alkaloid, quinine, for example, is, so far as we know, confined to the genus Cinchona; the bitter principle Aloin is not known to occur elsewhere than in the genus Aloe, and the very poisonous glucoside, digitoxin, has never been met with in any plant except the Foxglove. Moreover certain species under some conditions develop products which, under different conditions are never produced.

This fact is also illustrated in the Cinchonas. When *these* plants are cultivated in European greenhouses they produce no quinine, nor do they when grown at either too high or too low elevations in their native Andes; on the other hand it has been found that by a proper system of cultivation in a highly favorable climate, such as the Neilgherry Hills of India, they may be made to yield three or four times the quantity of alkaloids that they do in the wild state, even in the portions of the Andes most favorable to the growth of these trees.

It is well known also that the potato tuber, when left to grow exposed to the full sunlight, develops a poisonous principle, solanine, which, when grown normally under ground, it does not possess. The steps, therefore, in the process of destructive change, vary within certain limits, in accordance with varying conditions or with various habits and inherited characteristics of the plant.

The wastes of the plant which are carried to the outside, or excreted, are chiefly gaseous substances, or vaporizable liquids. For example, carbon-dioxide is returned to the air, water escapes as watery vapor, and portions of the volatile oils are gotten rid of in the same way. Most other wastes are retained in the interior of the plant, sometimes as deposits in cell-walls, sometimes stored in secretion cells, laticiferous tissues, secretion reservoirs, etc. Silica, however, and wax are deposited in the cuticle or at the surface of plants, and some calcium carbonate is carried out in solution in the water discharged from the water-pores of some plants.

Influence of Temperature on the Life of the Plant. The vital processes of the plant can only go on within certain limits of temperature. If it be too low, the seed will not germinate or the bud unfold, and if it be increased beyond certain limits, life is at first suspended and then destroyed. For each species of plant there is a minimum temperature below which activity ceases, an optimum temperature at which its activities are greatest, and a maximum temperature which cannot be exceeded without stopping the vital processes. These temperatures differ for different plants. Some, as the Red-snow plant of the Arctic regions, thrive at a temperature very near the freezing-point while others, as the Vanilla plant, cannot flourish except in the tropics.

A very low temperature as well as a very high one may cause the death of a plant, but the facility with which it is destroyed by either will depend upon the amount of water in its tissues. Dry seeds and spores have in some instances been found to endure an extremely low temperature without destruction of their vitality, while the vigorously growing plants of the same species were unable to endure even a slight frost. Similarly, a seed will endure a temperature many degrees higher than will the actively growing plant which springs from it.

It seems evident that when plants are killed by frost, it is on account of the formation of ice crystals by the withdrawal of water from the protoplasm, thus seriously disturbing the equilibrium of the cell contents, and probably setting up destructive chemical changes. The life of a plant that has been frozen may, however, often be saved by thawing it very slowly, when if rapidly thawed it would perish. Much, though, depends upon the habit of the plant. Too high a temperature kills by coagulating the albuminoids and destroying their power of absorbing the water. Few actively growing plants can endure a temperature higher than 122° F.

Influence of Light on the Life of the Plant. It has already been shown that green plants are dependent on light for their power to assimilate, and as all other organisms are dependent, in the long run, on the work done by green plants, light is indirectly essential to all life. Those organisms, however, which do not contain chlorophyll are not directly dependent upon it, and hence may thrive in darkness. Give a fungus the decaying organic matter on which to grow and it will flourish in the blackness of the deepest recesses of a cave. Even those cells of the chlorophyll-plant which do not contain green coloring matter are able to discharge their vital functions in darkness as well as in the light. Light is essential only to the construction of organic out of inorganic matters; it is not necessary for carrying on the oxidizing changes that take place in the plant. A seed will germinate in absolute darkness, but the plantlet will cease growing and perish as soon as it has exhausted the nutrient matters which were stored up for its use. A potato tuber permitted to grow in a dark cellar will apparently make a very vigorous growth, but when the shoots have exhausted all the nourishment stored up in the tuber, growth ceases, and if a comparison be made between the dry weight of the tuber at the beginning, and that of the sprouts and exhausted tuber at the close of the experiment, it will be found that there has been no increase; no new material has been added. Moreover, in plants thus growing in darkness, chlorophyll very rarely develops; both leaves and stem have a blanched appearance instead of the normal green.

It has been found that the part of the spectrum which has the greatest influence on assimilation is that which has the greatest illuminating power, namely, the yellow, but white light is more effective than any one of its component colors.

Light, also, by influencing the growth of the plants, or by the stimulant effects it exerts upon the living matter of their cells, gives rise to certain movements; but these may be more appropriately considered under the subject of the movements of plants, which will be taken up farther on.

Parasites and Saprophytes. It is evident from all that has been said, that chlorophylless plants, including saprophytes, which derive their sustenance solely from decaying organic matter, and those parasites which obtain all their food from living organisms, are to be regarded as destroyers, rather than builders. They are like animals in this respect. Their energy is derived from the tearing down of what others have built up. The line which separates such organisms from ordinary green plants is, however, not always sharply drawn. There are various degrees of saprophytism and parasitism. Many green plants are partly saprophytic, since they do not thrive except when well manured, or abundantly supplied with decaying organic matter. Insectivorous plants, like Sarracenia and Darlingtonia, must be regarded in the same light.

Many plants, like the Dodder, are completely parasitic; they develop no foliage leaves and no chlorophyll, and they draw their sustenance exclusively from the elaborated juices of other plants. Plants like the Mistletoe, however, are only partially parasitic, for, though this plant grows on other plants, sending its roots into their tissues and absorbing their juices, its leaves contain chlorophyll, and it, no doubt, assimilates some carbon-dioxide on its own account. Moreover, most green plants consist partly of chlorophyll-bearing cells, and partly of chlorophylless ones, and the latter may be regarded as parasitic on the former. Flowers and ripening fruits also, like true parasites, continually absorb oxygen and give off carbon-dioxide, and they as effectually drain the vegetative portion of the plant of its resources, as the Mistletoe does the Elm on which it grows, or the giant Rafflesia does its host-plant.

PRACTICAL EXERCISES.

1. Take a branch three or four inches long cut squarely off from a thriftily growing plant of Anacharis Canadensis, an aquatic very common in slow streams and ponds, without permitting the rest of the plant to dry, wipe the water off from the cut end and apply a little shellac varnish, permitting this to get thoroughly dry. With a needle-point now puncture a minute hole in the varnished end and then immerse the plant, this end upward, in a narrow jar containing pond or spring water. Expose it now to the light, and if the experiment has been properly conducted, small bubbles will be seen to issue in rather rapid succession from the aperture in the varnished end of the stem. These bubbles have been proven to consist chiefly of oxygen gas.

Transfer the jar to a dark room, and after it has remained there for a few minutes examine. It will be found that no gas is now given off. The evolution of bubbles will again take place, however, on restoring it to the influence of the sunlight.

Lower the temperature of the water by packing ice around the jar, and the evolution of gas again ceases, but it begins again when the temperature is permitted to rise sufficiently.

Now pour off the pond or spring water and substitute for it some freshly distilled water, or what will answer equally well, some spring water that has been boiled for some time to expel the dissolved carbon-dioxide; then expose the plant to strong sunlight as before. No gas will now be evolved; but it will immediately begin again if carbon-dioxide be introduced into the water. This may be done by simply shaking the water in a deep glass jar in the bottom of which a candle has been permitted to burn for a few minutes, or enough may introduced by merely blowing the breath into the water by means of a tube.

2. On a cold winter's day remove a branch of Hickory, Butternut or Maple and bring it into a warm room; the change of temperature, causing expansion of gases in its tissues, soon produces bleeding from the cut surface. Take the branch out into the cold again and the bleeding stops. The experiment may usually be repeated several times with the same branch. What is the cause of the flow of sap from the Maple tree when tapped in early spring?

3. Obtain four small flower-pots, and, having filled them with good black earth, plant in one of them a few grains of barley, in another a few of wheat, in another some of Indian corn, and in the fourth some seeds from a pumpkin. Keep them all moist, though not too wet, and let the room in which they are placed be maintained at a constant temperature of about 45° F. At the end of a week examine; the barley and wheat grains will probably be found in various

stages of germination, while no evidence of it will be seen in the Indian corn and pumpkin seeds.

Renew the experiment as regards the latter two, planting the pots with fresh seeds, lest the others may have been injured in the previous experiment, this time subjecting them for the same period to a constant temperature of about 60° F. If the seeds are good, both kinds will now germinate.

Vary the experiment by planting the pots anew with the same seeds as at first, but now subject them to a temperature of about 85° F., and after a few days examine. The seeds will be found to have germinated much more rapidly, and at the end of a week's time to have made a much greater growth than in either of the previous experiments.

When the plants have attained a height of two or three inches above the soil, try the following experiment: Place the pot containing the barley plants in a tin pail, and sink the latter nearly to its brim in a larger vessel containing water; now, after loosely covering the vessel and inserting a thermometer bulb, heat the water very gradually, so that the temperature of the pot and its contained earth and plants will rise *pari passu*. When the temperature of the water has reached 122° F., remove the source of heat and let the water slowly cool to the normal temperature of the room. Repeat the experiment with each of the other seedlings, and after the plants have stood exposed to the air a few hours, note the results in each case.

4. Remove a few leaves from a Begonia, Pelargonium or any common plant, weigh them accurately, and then place them in a clean capsule and heat them for a considerable time to a temperature not exceeding 212° F. That this temperature may not be exceeded, the heating had better be done over a water bath. When thoroughly dried, again weigh them, and the difference between this and their former weight will represent the proportion of free water that existed in their tissues. Calculate the per centage of dry solid matter and of water.

Now enclose the dried leaves in an iron tube, such as a piece of gas-pipe, and having sealed up both ends with fire clay, subject the tube to a red heat for some time. After the tube has been thoroughly cooled, unstop the ends and carefully remove the leaves. They will be found to be carbonized, but their original form will be retained, even the finer veins and stomata being perceptible under a magnifying glass. Weigh them, and the weight represents the mineral constituents, or ash plus a much larger proportion of carbon. A part of the carbon has been driven off by heat in the form of volatile compounds. With care the remaining carbon may now be burned out by heating the leaves to redness for sometime in an open tube, but care must be taken lest the ashes be blown away in currents of air and lost. When the process is completed, weigh the ash and calculate its per centage.

5. Cut off two branches of the House Geranium (Pelargonium zonale) selecting those of nearly equal size and age, and subject them to cold a few degrees below the freezing-point, until the tissues are frozen. Remove one to a warm room and let it thaw rapidly. Submerge the other in a considerable quantity of ice-cold water, and let the containing-vessel stand in a moderately warm room until it has acquired the temperature of the room. The immersed

branch will have been very slowly thawed. Now compare its condition with that of the other branch. One is comparatively uninjured and may even be made to grow, while the other is completely wilted and cannot be revived.

Try a similar experiment with two potato tubers.

6. Obtain in autumn or late summer some seeds of the common Dodder, a parasite. Plant them in a flower-pot and cause them to germinate, keeping the temperature of the pot at about 85° F. Examine the embryo of one of the seeds after germination has begun. It looks like a simple coiled thread, no cotyledons being developed, although it belongs to the great sub-class of Dicotyledons. In becoming a parasite it has apparently forfeited its seed leaves, and it will be observed as the embryo develops, that it forms no true leaves. It is in fact all stem, and even this seems modified into a tendril. Observe the slender, thread-like stems push out of the soil and circumnutate in search of a support. If no living stem or leaf be found to which they can cling, they soon wither away, for no chlorophyll is developed in them, and they are therefore incapable of assimilating mineral food ; but if some green plant be placed near, they will soon twine about it, sending sucker like roots into its tissues, and growing rapidly by deriving nourishment from it, perhaps even destroying the life of their host.

CHAPTER IV.

MOVEMENTS OF PLANTS.—SENSITIVENESS OF PLANTS. REPRODUCTION.

Movements of Plants. Although some plants, like the so-called Rose of Jericho, wither during the dry season and are blown by the wind, often to great distances over the sandy plains, but resume their verdure and send forth blossoms when they reach moist soil, or at the advent of the rainy season, strictly spontaneous movements of transition or locomotion are confined, as we have already stated, to the flowerless plants, and are most conspicuous among the lowest forms. They are exhibited chiefly by isolated cells, or by small colonies of cells. This is not because the protoplasm of higher plants has really less activity, but rather because it is mainly confined within rigid walls, so that the young and growing parts, or those, at least, in which the cell walls are thinnest, are the only ones free to move.

Locomotion in plants exists under three modifications, the *amœboid*, the *ciliary*, and a creeping motion of ill-defined character, such as that observed in many Diatoms, Desmids, etc. Plants that exhibit amœboid movements are unicellular and destitute of a cell-wall. The movement is a slow, creeping one, accompanied by constant changes of form, or the throwing out of processes resembling the pseudopodia of Rhizopods. It is undoubtedly the most primitive form of locomotion, and is exhibited only by the simplest living forms, or by more complex ones in the earlier stages of their development. It is illustrated in the Myxomycetes, Fig. 466.

Ciliary motion is accomplished by means of delicate hair-like or lash-like projections of the protoplasm, called cilia. In these organs, the ordinary protoplasmic contractility has acquired a high degree of development to suit them to the functions of locomotion, and by their rapid bending to and fro, the cell to which they are attached is propelled through the water in which it lives. While amœboid movement is slow and creeping, this is conspicuous for its rapidity, and is to be regarded as a higher development. It is observed in many mature plants belonging to the lower orders, examples of which are illustrated in Figs. 484 and 485, and in the reproductive spores of the great majority of flowerless plants. See Figs. 486, 487, 488 and 489.

The mechanism by which the slow, gliding, or sometimes jerky movements of Diatoms and Desmids is accomplished is not yet understood, though there can be no doubt it is attributable to the same fundamental property of contractility that lies at the foundation of all other spontaneous movements in plants.

Movements not Locomotive. (1) First to be noticed among these is the movements of the protoplasm within the cell-wall. In some cells, for instance, those of the stems and leaves of Chara and Nitella, the leaves of Vallisneria, many hairs, such as the stinging hairs of the Nettle, those on the filaments of Tradescantia, etc., the phenomenon is conspicuous, and there are few things more wonderful than to watch them under the microscope. While, however, they are more obvious in these examples, there is no doubt that they take place more slowly in all living cells. As regards their nature, they are streaming movements in the bands and plates of protoplasm that cross the cell, in the endoplasm and about the nucleus, or gliding movements of the great mass of the protoplasm around the interior of the cell, or sometimes crossing from one wall of the cell to the other. In cells containing chlorophyll-bodies, the latter very commonly assume a different position, in strong light, from that which they occupy when the light is greatly diminished. These changes of position are due to the movements of the protoplasm in which they are imbedded. In strong light they ordinarily gather along the side walls of the cell, or those which are perpendicular, or nearly so to the surface of the organ, while in dim light or darkness they congregate along the outer and inner walls. In Fig. 464, *a* is a cell from the spongy parenchyma of the leaf of Oxalis acetocella that has been exposed to weak or diffused day-light; the corpuscles are nearly evenly distributed along the walls parallel to the surface of the leaf. *b* shows a similar cell from a part of the leaf which has been exposed for a short time to direct sunlight; the chlorophyll-corpuscles are here seen distributed along the walls which lie perpendicular to the epidermis. *c* shows the position of the corpuscles in a cell which has been exposed for a longer time to direct sunlight. They are now massed together along the walls perpendicular to the surface of the leaf. These protoplasmic movements are all closely related to the amœboid movements above described, and would doubtless result in similar movements of locomotion were it not for the limitations imposed by the cell-wall.

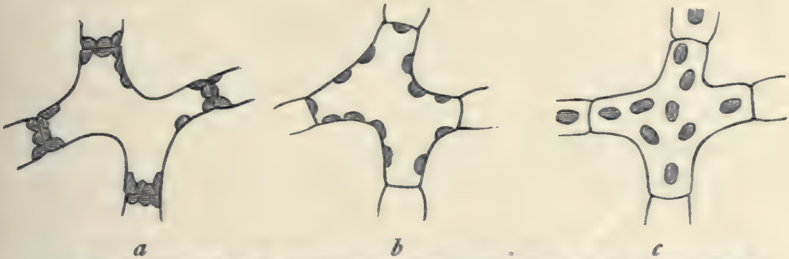


Fig. 464.—Cells of the lowermost layer of spongy parenchyma from the leaf of Oxalis acetocella, seen in a direction at right angles to the surface of the leaf. *a*, plane position of chlorophyll-corpuscles in diffused light; *b*, profile position after short exposure to the sun; *c*, position after longer exposure to the sun. After Sachs and Stahl.

(2) *Geotropism.* By this is meant those movements of growth, the direction of which is determined by the stimulus produced by gravity on the growing organs. It has been ascertained by planting a germinating seed on the rim of a wheel which was made to rotate in a vertical plane with a velocity sufficient to produce a considerable centrifugal pull at the circum-

ference, that the stem grew inward toward the centre of the wheel, or in a direction opposed to the pull, while the root grew outward from the centre, or in the same direction as the pull, indicating that in the ordinary growth of plants, gravity is the cause of the downward trend of the root, and also that of the upward trend of the stem. This conclusion is confirmed by other experiments. The condition of the growing tissues of the root is such that when that organ is stimulated by a constant downward pull it grows downward, while the different condition of the tissues of the stem causes that organ to grow in the opposite direction under the influence of the same stimulus. Under ordinary conditions, other forces, as we shall presently see, more or less modify the action of gravity; still it is mainly this which determines the position of the various organs of the plant with respect to the horizon. It is not only the chief cause of the downward growth of the main root of a tree, and of the upward growth of the stem, but it has much to do with the horizontal or oblique growth of the branches and leaves, and if any young and growing organ be by any cause diverted from its wonted direction, it tends to resume its normal direction again when the disturbing cause is removed. An organ which grows directly downward or in the direction of the pull of gravity is said to be *positively geotropic;* one which grows directly upward, or in opposition to that pull, is said to be *negatively geotropic* or *apogeotropic*, and one which assumes a position at right angles, or nearly so, to the pull is said to be *transversely geotropic.*

(3) *Heliotropism.* This term is applied to movements caused by the stimulant effects of light. The effect may be either to cause the organ to curve toward the source of light, or to bend away from it. In the former case the plant or organ is said to be *positively heliotropic*, and in the latter, negatively heliotropic or *apheliotropic.* Plants growing in the open sunshine of course always have one side more strongly illuminated than the other, but owing to the diurnal motion of the earth, the effect of which is to cause the direction of the light to constantly change, and owing also to the slowness with which most organs respond to the stimulus, movements of this character are not ordinarily conspicuous. It would not be difficult to prove, however, that the position which leaves and some other organs assume is due

in part at least to the stimulant effects of light. In the case of a few plants, like the sunflower, when they are young and actively growing, the sensitiveness to light is so great that the leaves and stem follow the sun during his daily course. When, however, we cultivate a plant in such a way that it receives its light chiefly from one direction, as for example when a house-plant is grown in a window, heliotropic movements are very noticeable. The stems, branches and petioles bend over toward the more strongly illuminated side, and the leaf-blades place themselves in a plane at right angles to the rays which fall upon them. If a seedling plant of almost any kind that has an erect habit, be fastened upright in a glass of clear water and placed in a window so that one side is presented toward strong light and the other toward darkness, in a few hours the stem will be bent perceptibly toward the light and the root away from it. The utility of these movements in enabling the plant to adjust the position of its organs in such a manner as to make them of the greatest service, is clearly evident. It is not always the case, however, that homologous organs behave alike under the same stimulus. The young shoots of the Ivy, when grown in a window, bend away from the light instead of toward it. But here also the movements are of advantage to the plant in enabling it to bring its rootlets into contact with walls, tree-trunks, etc., and so to climb. The negatively heliotropic movements of the rootlets of this and other root climbers, and of the tendrils of the Virginia Creeper and a few other climbers, subserve the same end.

But movements of heliotropism are not confined to multicellular organs ; they are often observed in organs composed of a single cell, or even in unicellular plants. The root-hairs of many plants, for example, are negatively heliotropic, while the spore-bearing hyphæ of some moulds are positively so, and if certain minute Algæ, such as Desmids, which are endowed with the power of locomotion be placed in a glass of water having one side exposed to strong light and the other to comparative darkness, it will be found, after a time, that the Algæ have accumulated on the illuminated side of the glass.

Experiment proves that the rays most concerned in producing heliotropic movements are those toward the violet end of the spectrum.

The phenomena of heliotropism are similar, in all essential respects, to those of geotropism, except that the force which causes the movement is light instead of gravity. In the one case it is the direction of a pull, in the other the direction of an ether vibration, which, acting upon the irritable living matter of the cell, brings about changes that cause the organ to place itself in a different position.

It has been found also that movements are sometimes produced by the ultra-red or dark heat rays of the spectrum, some organs moving toward the source of heat, and others away from it. The phenomenon is called *thermotropism*.

(4) *Hydrotropism* is a term applied to organs which, like young roots, have been found to curve toward a moist surface. It is a source of great advantage to a plant, since, by means of it, its roots are, so to speak, able to seek out the moister and avoid the dryer and ordinarily less nutritive portions of the soil.

(5) *Circumnutation*. This term was first applied by Darwin to the revolving movements observed in the tips of the young and growing shoots, roots and leaves of the higher plants. The movement consists in a bowing of the organ successively to all points of the compass, thus causing its tip to describe a figure approximating a circle, or, more commonly, an ellipse. It is caused by the formation, lengthwise, of the organ of a line of growth which travels laterally around the organ.

The circumnutating movements of the growing radicle doubtless aid it in penetrating the soil; those of the upper internodes of twining plants are the means by which they climb; the corresponding movements of some other climbers constitute an efficient means by which they are able to bring their climbing organs—rootlets, sensitive petioles or tendrils—into contact with a support, and so secure a hold by which they may raise themselves toward the sunlight; and the tendrils themselves are also commonly endowed with circumnutating movements which serve the same useful purpose. This is the most important of all the plant movements. It is also regarded by Darwin as the fundamental form, of which the others are modifications. The phenomena of geotropism, heliotropism, etc., are caused by the modification of this primitive form by external stimuli of various kinds, as gravitation, light, heat, etc.

(6) *Nyctitropic*, or Sleep Movements. The leaves of Oxalis, of Clover, of the Acacias, and the compound leaves of many other plants, have been observed to assume positions quite different at night from those they occupy during the day. See Figs. 465 and 466. By day the leaflets are expanded so as to expose as large a surface as possible to the light, but at night they droop and become pendant from the axis on which they are borne, or, in some instances, fold together so as to present to the sky as little surface as possible. These movements are serviceable to the plant in preventing excessive radiation of heat at night. In many plants the combined upper surfaces of the leaves amount to an enormous total, and if this be spread out to the sky, on a clear night, the loss of heat by radiation must be very great—so great, in fact, that serious injury to delicate tissues would often result, especially in the case of plants inhabiting dry regions, or open plains. Experiment has proved that when the leaves of nyctitopic plants are pinned out horizontally, so that they cannot close, they do suffer injury from this cause, the leaflets often turning brown and dying after a night's exposure.

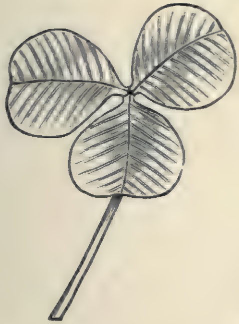


FIG. 465.

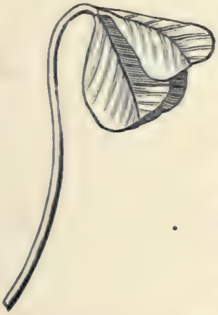


FIG. 466.

FIG. 465.—Leaf of White Clover with the leaflets in their diurnal position.

FIG. 466.—Leaf of White Clover with leaflets in the position which they assume at night.

The cotyledons of many germinating seeds of dicotyledonous plants exhibit nyctitropic movements in a conspicuous manner. Sometimes they droop at night like the leaflets of Oxalis, while in other cases they rise from the horizontal to the vertical position, closing over the plumule, and thus protecting it, as well as their own upper surfaces.

The flowers of many plants also show similar movements. Some open in sunshine and close at night, or in cloudy weather; others, like the Evening Primrose and the White Lychnis, have the opposite habit of opening by night and closing by day.

Some flowers have very regular hours of opening and closing; for example, according to Linnè and De Candolle, the Purple Morning-glory opens at 2 A. M.; the White Water-lily at 7 A. M.; the Blue Passion-flower at 12 M.; the common Evening Primrose at 6 P. M., and the Night-blooming Cereus between 7 and 8 P. M. Sometimes the movements appear to be dependent on variation in the intensity of light; at others they seem to be quite independent of it, as in the case of the Goat's-beard (Tragopogon pratensis), which opens in the morning and closes at or before noon.

The opening and closing movements of the floral organs are accomplished, like those of ordinary leaves, by unequal growth, or, sometimes, mainly by unequal turgescence of the upper and under surfaces of each organ, or of its basal portion.

So far as the utility of these floral movements are concerned, they mostly have reference in some way to cross-fertilization. The closing of a flower at night, or when the sky is darkened at the approach of a storm, serves to prevent the wastage of its nectar and pollen by dew and rain, and the closing at night, in some cases at least, prevents the access of night-flying insects that could not be serviceable to the flower in cross-fertilization, while in the reverse case of flowers that open by night and close by day, they are mostly adapted to cross-fertilization by night-flying insects, and it is an obvious advantage to them to protect themselves, by closing, from unserviceable day-flying insects.

Besides these, there are other more conspicuous movements observed in some plants, the use of which is not so well understood. The Telegraph Plant (Desmodium gyrans), a native of India, affords a conspicuous example. The plant has compound leaves, with the leaflets in threes, two small lateral ones, and a much larger terminal one. The lateral leaflets are in constant motion, sometimes moving up and down, and sometimes circularly. The motions are often rapid, particularly in bright sunshine, and they are frequently unequal and jerky.

These movements, as well as those described as nyctitropic, are also to be regarded as modifications of circumnutation.

Irritability. Attention has already been called to various phenomena under this head, such as the sensitiveness to contact shown by the leaves of the Sensitive Plant, by those of Venus'

Fly-trap, by the stamens of the Barberry, etc. Phenomena like these are by no means exceptional, though in many cases much less conspicuous. In fact, all the spontaneous movements of plants that have been described are evidences of irritability. They take place, that is, in response to a stimulus of some sort communicated to the living protoplasm. The irritant or stimulant influence may be gravitation, light, heat, chemical agents, electricity, or mechanical shock, pressure or contact.

If we experiment upon a mass of naked, living protoplasm, such, for example, as the plasmodium of one of the Myxomycetes, we find that a shock causes it to contract, whether the shock be that produced by a mechanical blow, or that caused by a current of electricity. Also, if we strike a young and growing shoot a smart blow, it will respond to the stimulus by slowly bending, the character of the movement it undergoes depending on the force and direction of the blow. Facts like these, and numerous similar ones, justify the conclusion already stated, that irritability is a property common to all living vegetable protoplasm.

Among the more interesting phenomena of this kind are the sensitiveness of tendrils and other climbing organs. Take, for example, the tendril of the Passion-flower. When young, it is straightened out and somewhat hooked at the apex, and is carried around in a circle by circumnutating movements. If, in the course of these, it fails to be brought into contact with an object suitable for it to cling to, it soon coils up into a close spiral, loses its sensitiveness, and finally withers away. But if the hook at its extremity comes into contact with the stem or branch of another plant or other suitable object, it is likely to catch upon it, the irritation of the contact causes it to bend around it and clasp it firmly, ultimately, if the shape of the object permits, forming two or three coils about it. The rest of the tendril then forms a double spiral, a part of which winds in one direction, and the rest in the opposite direction, and at the same time its tissues acquire great firmness and elasticity. The spiral coils thus formed serve the double use of drawing the plant closer to its support, and of acting as a spiral spring to prevent it from being torn away by a sudden strain, such as that produced by a gust of wind.

The tendrils of some species of Ampelopsis, as we have seen, are apheliotropic, and by virtue of this property, and since walls, tree-trunks, etc., are nearly always less strongly illuminated than the sky, they bend toward such surfaces. If they are able to reach them, the sensitive tips of the branches are irritated by the contact, and they enlarge, become flattened into sucker-like discs, which, by means of a cement they secrete, become glued to the surface, affording them a secure hold upon it. The tendrils and their branches then coil into spirals, and acquire great firmness and elasticity, in the same manner as those of the Passion flower above described. The plant is thus enabled to climb over perpendicular walls of rock, the sides of buildings, etc., objects to which most tendril- and leaf-climbers are unable to cling. A portion of Ampelopsis Veitchii is shown in Fig. 18, Part I.

Not less wonderful is the sensitiveness of young roots, by reason of which they are able, during their progress through the soil, to avoid obstacles or turn aside from their course to reach supplies of moisture.

Experiment proves that plants, like animals, may have their sensitiveness impaired or destroyed by exposure to anæsthetics like ether, chloroform, etc.

If the Sensitive-plant be placed in a bell-jar under which a little chloroform is permitted to evaporate, its leaves very soon cease to respond to the touch ; if the exposure be long continued, it fails to recover sensitiveness, and dies ; but if it be of short duration, it soon comes to itself and the possession of its normal powers. This affords another proof that irritability in the plant is essentially the same thing as irritability in the animal.

How irritant impulses are communicated from one part of an organ to another in the plant, is not yet well understood. Plants, of course, do not possess nerves by which such impulses can be conveyed. They must travel from cell to cell, and it is difficult to understand how this can be, unless the living matter is continuous from cell to cell, through the cell-walls.

By using sulphuric acid to dissolve away the cell-walls, the protoplasm has been found, in some cases, to be thus connected by very delicate threads. It is only reasonable to suppose that this continuity is not exceptional, but that it exists in all organs capable of transmitting an irritant impulse from one part to another.

Reproduction. All plants possess the power of giving rise to new individuals, and this may take place in either one of two general ways, (1) by some form of cell division, and (2) by the union of two cells, at first distinct. The former mode is called *asexual*, and the latter, *sexual* reproduction. In the asexual mode we may distinguish between *vegetative* reproduction, in which the parent plant throws off or separates from itself ordinary vegetative cells, and *spore-reproduction*, which consists of the separation of specialized cells called spores. The vegetative mode is represented in a very simple way by many of the low forms of plant life. The Red Snow-plant of the Arctic regions and the Bacteria multiply with astonishing rapidity by the simple process of fission. Except that the cells become independent of each other, instead of remaining together to form colonies, the process resembles the cell-multiplication which takes place in the higher plants during growth. In the yeast and its allies, new individuals are formed by budding or by internal cell-formation. Most plants, even those belonging to the higher orders, have the power to multiply vegetatively. The Common Liverwort (Marchantia), for example, produces on the surface of its fronds little cup-like organs from which rounded masses of green cells are set free to give origin to new individuals; the Tiger Lily reproduces by means of bulblets formed in the leaf-axils; and many plants, multiply, as we have seen, by bulbs, tubers, stolons, offsets, etc.

Spore-reproduction by the asexual process is exemplified in many flowerless plants. The spores which are produced in such enormous numbers on the gills of the common Mushroom, many of the motile spores so commonly produced by the fresh-water Algæ, and the ordinary spores of Equisetums, Club-Mosses and Ferns, are all products of this process. The spores are commonly borne in a special organ, called a *sporangium.*

There are also two principal modes of sexual reproduction. The simplest is by *conjugation*, which, as already explained, means the union of two cells that, to all appearance, are precisely alike. There are two varieties of this mode, one in which the union takes place between ordinary vegetative cells, as in Spirogyra, Fig. 397, and the other in which the union is between zoöspores as in Pandorina, Fig. 484, *b* and *c*. The product, in either case, is callen a zygospore.

The second mode is by *fertilization*, or the union of two distinct cells, one of which is usually of larger size and passive, the germ cell; and the other, smaller and commonly active, the sperm cell. This mode is much the more common, and it exists in many varieties. It is the only sexual mode observed in all the higher types of plants. The description of its different modifications is, however, reserved for Part IV, where they will be treated of in detail in our study of the principal types of plant life.

There are few things in nature more wonderful than the results produced by fertilization. These, as we well know, are not confined to the immediate effects upon the fertilized cell itself, resulting, in the case of flowerless plants, in the production of one or more spores, or in the case of flowering ones, in the development of an embryo, each capable of giving rise to a new plant; but the effects reach to adjacent organs, and often modify them in a profound manner. When Apple, Pumpkin or Melon blossoms are fertilized, not only do the ovules undergo great changes of structure and size, but the entire ovary walls undergo a very remarkable development. In the Strawberry the influence extends to the receptacle, and in the Checkerberry to the calyx, in each case resulting in an extraordinary development of the organ.

In the case of other organs the effect of fertilization may be of the opposite character, namely, to cause their rapid withering and decay, probably by a diversion of nutriment from them to other parts. This is nearly always the case with the corolla, and frequently also with the calyx, as every gardener knows, for if he wishes to prevent, as long as possible, his flowers from withering, he pinches off the anthers before they are ripe, or takes some other means to prevent fertilization.

How far these effects are the result, more or less remote, of the stimulant effects of the fertilizing material on the germ-cell, and how far they are due to the stimulant effects of the pollen-tube on other tissues with which it comes in contact, is not yet known; but there are numerous facts to show that the effects cannot all be due to the fertilization of the ovule.

The Orchids, for example, show a very considerable development of the ovary as a direct result of pollination, before the pollen-tubes reach the ovules. There are good reasons, moreover, for believing that the development of seedless apples, and other seedless fruits, is due, in many cases at least, to the stimulant effects of the pollen on the other tissues of the ovary when the fertilizing material has failed to reach the ovules.

But, however this may be, there cannot be the least doubt that fertilization makes a profound impression on the entire economy of the plant. There are not only *a priori* reasons for believing this would be the case, but there are well authenticated instances where the character of the flowers and fruits produced by plants, have been more or less permanently modified as the result of crossing with a plant which produced a flower of a different color, or a fruit of a different quality.

The question naturally arises, why two modes of reproduction, the asexual and the sexual, should exist among plants.

Comparing the two processes, we find that the asexual mode is simple, and involves little expenditure of energy on the part of the plant, while the other often requires for its consummation complicated machinery, and is an expensive process, a heavy draft on the vitality of the plant. Why, then, does the sexual mode exist? Science cannot yet give a complete answer to this question, but it may be partly answered by observing the difference between the offspring produced by the two processes. That of the asexual presents very little variation from the parental form. If we wish to perpetuate a fine variety of fruit, we do not sow the seeds, but rather multiply the plant by grafting, budding, layering, or by some other process of division, imitating nature's modes of asexual multiplication. Should we plant the seeds, we would probably obtain a variety of fruits, those from different seeds differing more or less from each other and from the parent form, and all, very likely, inferior in excellence to the fruit we wish to perpetuate. Now, variation, which in this instance we wish to avoid, is of immense advantage to plants in their struggle for existence. The physical conditions of the earth's surface are slowly but constantly changing, and by variation, plants are constantly adapting themselves to these ever-changing conditions. Those varieties best adapted to the existing conditions are the ones to survive; those unfitted for them must perish.

The reason of the greater variation in sexually generated offspring is to be sought for in the double parentage. The offspring of two individuals, or the product of two distinct lines of descent, must occasionally, at least, possess stronger characters—characters better adapted to insure the survival of the individual—than would be possible where the selection is made from one individual, or from one line of descent. Hence, the adoption and continuance of the more costly process of sexual reproduction is not an instance of extravagance on the part of nature, but is rather a wise economy of her forces—an investment which brings a profitable return.

PRACTICAL EXERCISES.

1. The stems, branches and leaves of various species of Chara and Nitella, the transparent leaf-cells of Vallisneria spiralis, the young stinging-hairs of the Nettle, the hairs on the filaments of Tradescantia Virginica, those on the filaments of Linaria vulgaris and those on the filaments of Lobelia syphilitica afford favorable objects for the study of protoplasmic movements in cells. The species of Characeæ which have the most transparent stems, are the ones to be preferred, and only low magnifying powers, say twenty-five or fifty diameters, are required for their study. The cells of Vallisneria require a higher magnifying power, preferably one of about two hundred diameters. The stamen and Nettle hairs require still higher powers, four hundred or five hundred diameters. When stamen-hairs are used, it is better usually to obtain those from unopened flowers. The cells are then more transparent and the movements may be more easily observed. All these objects should be mounted in water with as little crushing or injury to the tissues as possible, as rough handling will often stop the movements of the protoplasm.

2. For the study of the change of position which chlorophyll-bodies undergo under the influence of light, the common Duckweed (Lemna trisulca), the leaves of such Mosses as Bryum roseum and Funaria hygrometrica or the prothallia of any ordinary Fern, being thin and transparent and having large chlorophyll-bodies, are favorable objects for study. In experimenting upon them, one part of the organ may be exposed to diffused light by covering it with paper, while the rest is exposed to direct sunlight. After sufficient exposure, the organ may be immediately examined microscopically, or the protoplasm may be first fixed by immersing the organ in alcohol or in solution of iodine. If the chlorophyll-bodies are rendered too transparent by the bleaching action of the alcohol, they may readily be stained by immersing them for a time in very dilute solution of methyl violet. The parts exposed to different conditions of illuminations may then be directly compared.

3. Take a few seeds of the common Bean, Vicia faba, and cause them to germinate on a damp sponge under a bell-jar. After the radicle has protruded from the seed-coats about one-sixth of an inch, remove one or two of the seeds from the surface of the sponge and fasten them by means of a little shellac cement to a small block of wood, in such a manner that the radicles will project

over the edge of the block, and be free to move. To each of the radicles, near its end, fasten by means of a minute drop of shellac varnish a delicate straight filament of glass about two inches long. The filament is readily made by softening a thin glass tube or rod in a gas-flame, and then rapidly drawing it out. The distal end should be blackened so that it may readily be seen. Now replace the seeds, with the block to which they are attached, under the bell-jar next one side, so that any movements of the blackened ends of the filaments may readily be observed through the side of the jar. By noting from time to time, with dots of ink on the side of the jar, the position of the filaments, very considerable movements will be observed.

Besides the circumnutating movements that may thus be studied, it will be seen after a time that the radicle has bent downward. This is a geotropic movement.

Experiment in a similar manner with germinating acorns and peas, and record the results.

4. Place a few of each of the above-mentioned seeds on the surface of moist sand, cover them with a bell-jar and keep them moderately warm. The radicles will, after a time, be observed to emerge from the seed-coats, bend downward and penetrate the sand. A few hours after this has taken place, carefully remove the germinating seeds, and it will be observed that numerous sand grains adhere to the radicles above their tips. Many of these still adhere to the radicles after rinsing them with water. On examining them with a magnifier, it will be found that they are firmly cemented to the root-hairs that have formed in great abundance above the apex of the radicle. So secure is their attachment that they can scarcely be dislodged without destroying the hairs themselves.

5. Plants of the Hop and Morning-glory are easily obtained, and in them the twining movements are readily studied. Begin the study in each case with the young stem just emerging from the soil. Observe that at first it grows erect, or nearly so, but after two or three internodes are formed, the upper one bends slightly to one side and begins its revolving movements. As this internode elongates and others are developed above it, the rapidity of movements for a time increases, and the circle described widens. But for each plant there is a limit, for when the internode attains its full growth, it becomes rigid and usually erect. Note in each case the average time it takes for an internode to complete a revolution, and how many revolutions are completed before its movements cease. It would be interesting to observe also how the movements are affected by different temperatures, and how by the presence or absence of light, or by light of different intensities.

To observe how these movements serve the plant for climbing, thrust one end of a thin stick into the ground beside the plant, and the stem will soon be seen to coil spirally around it. Observe that the Hop twines with the sun, or in the same direction as the hands of a watch move, while that of a Morning-glory twines in the opposite direction.

6. The common garden Tropeolum and the native Clematis Virginiana, so common in our woods, both afford good examples of leaf-climbers. Observe with care the movements of the young internodes in each of these species, the

average time it takes in each case to complete a revolution, and note the utility of these movements in bringing the sensitive petioles into contact with objects suitable for support. Observe also the change that takes place in the thickness and strength of the petioles after they have clasped a supporting object. Watch carefully also to see whether, in either of these leaf-climbers, any circumnutating movements of the leaves themselves are discernible.

7. Observe in the common Ivy that, when grown in a window, its leaves turn toward the light, while the young shoots bend away from it, and that the numerous secondary roots thrown out along the side of the stem all point directly away from the light. Compare with these the rootlets of the Trumpet Creeper and Poison Rhus. The apheliotropic tendrils of the various species of Ampelopsis are also very interesting subjects of study.

The common basket plant, Saxifraga sarmentosa, produces pendent stolons, or runners, which, when the plant is grown in a window, turn away from the light.

Another instructive experiment is to obtain a glass of water from a pond which contains numerous microscopic green organisms, such as Desmids, the spores of Algæ, etc., a condition which is generally indicated by the greenish tinge which the organisms communicate to the water. Place the glass in a window for a few hours and then examine. On the side exposed to the light a green incrustation will be observed, showing that the organisms have moved toward this part of the enclosure and there accumulated.

8. Try the following experiment in hydrotropism. Cause some peas to germinate in moist sand. After the protruding radicles have a length of about half an inch, remove the peas from the sand and fasten them to an apparatus constructed as follows: Take a piece of wire gauze or mosquito-netting, and having arranged a quantity of Sphagnum moss, fasten the gauze or netting around it in such a manner as to form a cylinder about an inch in diameter and about six or eight inches long. In a row along one side of this attach the germinating seeds in such a manner that when the cylinder is inclined at an angle of about 45°, with the seeds on the lower, sloping surface, the radicles will point nearly perpendicularly downward. Having secured the cylinder in the position thus indicated, keep it in a moderately dark, and not too dry room, and keep the moss saturated with water for twelve hours or more, and then examine. If the experiment has been carefully conducted, it will be observed that the radicles have deviated from their normal downward course toward the moist surface of the cylinder.

9. Sleep-movements may readily be studied in the leaves of any of our species of Sorrel (Oxalis stricta, O. violacea or O. acetocella), in those of the common Locust (Robinia pseudacacia), and in those of the Sweet Clover (Melilotus alba). Observe the movements carefully and make drawings illustrating the diurnal and nocturnal positions of the leaves in each of these species.

The opening and closing movements of the following flowers may also readily be observed: The Morning-glory, the Dandelion, the Sow-Thistle, the Evening-Primrose, the Four-o'clock, and the white Water-lily. Note the time of opening and closing in each case when the weather is clear, and observe whether cloudy weather in any way modifies the movements.

10. In the summer season, by searching among the pieces of moist tan-bark about a tannery yard, specimens of Æthalium septicum, one of the Slime-moulds, may usually be found. They form yellowish, gelatinous masses of various shapes and sizes, sometimes as large as a pigeon's egg or larger. Having found one of these plants, support the piece of bark to which it adheres in an upright position under a bell-jar, with an end resting on a moistened sponge, and expose the jar to diffused light in a window, in such a manner that the plant will be on the illuminated side; after a time it will be found that it has moved around to the shaded side of the bark, showing that it is sensitive to light.

With care it may be made to creep upon a glass slide, and the pseudopodia and streaming movements of the protoplasm may then be studied under a compound microscope.

If the mass be struck a sudden blow, as with the flat side of a knife-blade, but not so hard as to crush or disorganize the protoplasm, it will be observed to contract, and its amœboid movements will cease for a time; but if left to itself for a while under favorable conditions, the movements will be resumed.

It will not be difficult to arrange an experiment so as to send a weak current of electricity through the mass after it has resumed its activity. One electrode of the battery should be placed gently in contact with one side of the mass and then the other should be brought into contact with the opposite side. The moment the circuit is completed, sudden contraction will be observed to take place as before.

11. On the young tendril of a healthy vine of the Wild Cucumber (Echinocystis lobata), place a piece of twine a few inches long, and allow it to remain for a few hours and then observe the result. It will probably be found that the tendril, in response to the stimulus, has bent toward the string. Continue the experiment, and observe and record the final result. The experiment may easily be varied in such a manner as to ascertain how small a weight of string will suffice to produce movement in the tendril.

PART IV.

VEGETABLE TAXONOMY.

CHAPTER I.

Value of Comparative Study. Vegetable taxonomy is that department of botany which treats of classification, or the arrangement of plants in groups or ranks according to resemblances and differences. The study of plants in their relationships to each other, distinguishing between differences which are superficial and those which are deep-lying, and noting how even the most diverse forms resemble each other fundamentally, is not only an interesting exercise, but one of the most necessary parts of botanical training.

It is not possible, either, to understand any one plant thoroughly, or even any one plant-organ, except by comparative study. We shall get, for example, a far more comprehensive view of the nature and functions of the leaf, if we compare the different modifications of it which occur on the Oak with those of the Pea, the Pitcher-plant, the Venus' Fly-trap, and the Clematis, than we should if we studied any one of them separately; so also we shall know more about the Rose plant if we study it in comparison with the Indian Corn, the Pine, the Fern and the Moss.

Moreover, it is a matter of great interest and importance to the student to obtain a clear conception of the vegetable kingdom as a whole, as a great system of life. Of course, it is not possible, even if it were desirable, within the limits of an ordinary life-time, to become acquainted with all of the two hundred thousand or more species of plants known to science; but to get some accurate knowledge of the principal types, and of their relations to each other, to become thoroughly acquainted with a few of the representative forms of each type, and to be well acquainted with the flora of one's own neighborhood, is both possible and of great importance to every intelligent man.

Classification and Naming of Plants. All plants are more or less nearly related to each other, not only in structure and function, but without doubt also genetically or by descent.

The forms that gladden the face of the earth to-day are the descendants of the sombre vegetation of the far-off Carboniferous Age, whose remains, in the form of coal, supply the civilized man of the present with fuel to warm his dwelling and drive his steam machinery; the coal plants, in turn, were descended from the still more remote and simpler vegetation of the Silurian seas.

We shall best understand what plant classification means, the relation of past to present forms, and of present forms to each other, by means of a symbol — by picturing to our minds the system of life as a great tree. This tree began its life in the very remote past, in some very simple form, probably a shapeless bit of living jelly. From this as a common trunk, as time rolled on, branches diverged, which have continued to develop and ramify, and spread wider and wider, until the present time. Some branches, however, that throve for a time, were overshadowed by others, and finally decayed and died; but there still remain innumerable twigs and small branches of the wide-spreading top; all else is buried in the debris of the past, its outlines only being traceable in the fossil forms which have been preserved to us. On examining the living twigs that remain, we naturally find them distributed into groups and clusters of various sizes. The members of a cluster of twigs we may trace back to a common branch, those of adjacent clusters similarly converge to other branches, and these again converge to larger ones, and so on. It is the business of the systematic botanist to move about among these twigs and branches of the great tree of vegetable life, and discover their real relationship to each other, to trace back the branches as far as possible toward the common trunk.

Thus botanical classification has for its object the discovery of the natural or genetic relationship of plants.

Looking about among the varied forms of vegetation, the botanist finds plants that closely resemble each other in form, structure and habits of growth, and which are distinguished from other forms by some constant structural difference. For instance, the Smooth Rose, wherever found, maintains its essential characteristics, and differs constantly in some particulars from the Dog Rose, the Carolina Rose, the Prairie Rose, etc. Such a form is typified by one of the twigs of our figurative tree, and we call it a *species.* Species often resemble each other, as do the different species of Roses just mentioned. Such a group of species we call a *genus*, and that to which the roses belong we name the genus *Rosa.* Just as species naturally fall into genera, so these, in turn, form higher groups, called *orders.* The genus *Pyrus*, for example, which contains the Apple, Pear and Quince, resembles that of Rosa in certain important and constant particulars in which it differs from all other plants. The same is true of the genus *Rubus*, which contains the Raspberries and Blackberries, the genus *Cratægus*, which contains the Hawthorns, and so on. These genera, therefore, are placed together in the order *Rosaceæ.* Similarly, orders which resemble each other form *classes;* classes which resemble each other are called *series* or *branches*, and these are the primary divisions of the plant *sub-kingdom.*

It must not be understood that groups of the same name are always equal either in the sense of being equally numerous in sub-divisions or individuals, or in the sense of being marked off with equal distinctness from other groups; on the contrary, they are often very unequal in both senses, as we should naturally expect if we bear in mind our figure of the tree. Some species for example, are rare, they contain but few individuals, and these may not fall into distinct sub-groups or varieties; while others are exceedingly numerous, and may be broken up into many varieties; some species, at least so far as existing forms are concerned, are sharply marked off from other species, while others shade so insensibly into other species, by reason of connecting forms, that it is often difficult to draw the line between them. So it is also with the higher groups, genera, orders and classes. When genera are large, they are often conveniently divided into *sub-genera*; large orders are commonly divided into *sub-orders*, and these, perhaps, again into *families* and *tribes.* Classes, also, are often divided into *sub-classes.* The terms *race* and *variety* are applied to subdivisions of species.

The relations of the different groups may be represented in the descending scale as follows:

SUB-KINGDOM,
  SERIES OF BRANCH,
    CLASS,
        Sub-Class
      ORDER,
          Sub-Order,
            Family,
              Tribe,
            GENUS,
                Sub-Genus,
              SPECIES,
                  Race, Variety.

In the classification of plants in a natural system, no one character or set of characters can be relied upon to the exclusion of the rest. The whole structure and development of the plant should be taken into account, in assigning it to its place in the system. It must not be understood, however, that all characters are of equal value, for this is far from being the case. For example, the numerical plan of the flower is of much more value in classification than the shape of the petals, and the structure of the pistil has more significance than the character of the stem, whether it be herbaceous or woody. Moreover, the same characters do not always have the same value in some groups that they have in others. The shapes of leaves, for instance, in some genera afford convenient and reliable means of distinguishing species, while in others, these organs are so inconstant in form as to be nearly worthless for the purposes of classification. In general, however, it may be said that characters drawn from the reproductive organs are of more value than those drawn from the vegetative, and those derived from structure are of more importance than those derived from the habits of the plant. The Elm and the Nettle, for example, resemble each other in important structural features, and belong to the same natural order, but their habits are widely different, the one being a pernicious pasture-weed, the other, one of the most magnificent and valuable of our forest trees.

In the naming of plants, the binomial plan of nomenclature, first brought prominently into use by Linnæus, is now universally adopted. This consists in applying the name of the genus and following it with the name of the species. According to this plan, the generic name must never be duplicated or applied to more than one genus, but the same specific name may be used again and again, providing it is appropriate and is not applied to more than one species of the same genus. The names, with rare exceptions, are either of Latin origin or Latinized from other languages. *Solanum tuberosum*, for example, is the name of the Potato plant, and *Gentiana crinita*, of the Fringed Gentian. The usage, it will be seen, is analogous to that employed in naming persons, except that the order of the names is reversed, the generic name corresponding to the surname, and the specific to the christian or given name. The plan has also obviously the same advantages.

As to the origin of botanical names, some have come down to us from remote antiquity. Of these *Petroselinum* and *Mandragora* are examples. The larger proportion, however, are of modern invention. Some of these were applied because of some useful property, real or fancied, which the plant was regarded as possessing; for example, *Scrophularia*, because the plant was believed to be useful in scrofula; and *Serpentaria*, because the plant was thought to be a remedy for the bites of poisonous serpents. Sometimes they were given in allusion to something in the appearance, habit, structure or behavior of the plant. *Podophyllum*, for example, has reference to the shape of the leaf; *Dendrobium*, to the epiphytic habit of the plant; *Utricularia*, to the fact that most of the species have small bladders on their leaves; and *Impatiens*, to the fact that the ripe capsules rupture explosively when touched.

Very commonly also names were applied in honor of some naturalist, either the botanist who discovered or first accurately investigated and described the plant, or some other naturalist of eminence; for example, *Linnæa* was named in honor of the great Swedish naturalist, and *Claytonia* in honor of Clayton, an early American botanist.

The first or generic name of the plant is always a noun, and should begin with a capital letter; the second, or specific name, may be either a qualifying adjective or a noun ; it is much more commonly the former, and then, if not derived from a proper name, should begin with a small letter, as in *Bartonia verna* and *Lithospermum hirtum ;* but if derived from a proper name it should begin with a capital, as *Menispermum Canadense*, and *Cynoglossum Virginicum*.

When the specific name is a noun, it may either be a proper name in the genitive case (corresponding to our English "possessive"), as *Berberis Fendleri* (Fendler's Barberry), and *Conyza Coulteri* (Coulter's Conyza) ; or it may be a common noun in the genitive, as *Polygonum dumetorum* (the Polygonum of the thickets), and *Salix desertorum* (the Willow of the deserts) ; or, again, the noun may be by apposition in the same case as the generic name ; the following are examples : *Chenopodium botrys*, *Panicum scoparius* and *Cypripedium calceolus*. In all these cases, if the specific name be a proper noun, it should begin with a capital ; if a common noun, with a small letter ; but names which have previously been used as the names of genera, and have been reduced to those of species, are regarded as proper nouns and capitalized, whether they were originally proper names or not ; the following are examples : *Piscidia Erythrina*, *Leptopoda Helenium* and *Aristolochia Serpentaria*. In a few instances specific names consist of two nouns, one in the nominative, and the other in the genitive, connected by a hyphen : *Panicum crus-galli*, *Carex crus-corvi*, *Taraxacum dens-leonis* and *Capsella bursa-pastoris*, are examples. Sometimes, however, one of the words is a noun, and the other a qualifying adjective, as *Ipomæa bona-nox*.

Rarely a specific name is derived from some other language than the Latin, for example, the noun *Kali*, in the name *Salsola Kali*, is derived from the Arabic, and the word *macrocarpon*, in the name *Vaccinum macrocarpon*, is from the Greek language.

In cases where species are sub-divided into varieties, the latter are designated by an additional name, as in the following examples : *Ranunculus hyperboreus*, var. *natans*, *Potentilla dissecta*, var. *glaucophylla* and *Hydrophyllum occidentale*, var. *Fendleri*.

A recognized rule among botanists is, that the name which should finally attach to a plant is that which was first published.

The publication, however, to be authoritative, must be accompanied by an accurate description of the plant. Of course, it has very often happened in the history of the science, that several different botanists have investigated and named the same plant, and the question which name should be adopted is sometimes a difficult one to determine ; some authors will perhaps adopt one name, and others another. To save confusion, in descriptive works it is customary to indicate, usually in abbreviation, the authority for the name. For example, *Veronica Anagallis*, L., *Ledum glanduiosum*, Nutt., and *Mertensia lanceolata*, D. C., the abbreviations standing for Linnæus, Nuttall and De Candolle, respectively.

The names applied to groups of plants higher than genus, have the adjective form, and qualify the word *Plantæ* understood ; for example, *Angiospermæ* (meaning plantæ angiospermæ, or angiospermous plants), is applied to one of the main divisions of flowering-plants, and *Rosaceæ* (meaning plantæ rosaceæ, or rosaceous plants), is applied to the natural order, which includes the Roses, Brambles, Pear tribe, etc. They begin with a capital, and terminate usually in *æ*, *eæ* or *aceæ*.

Names applied to families are commonly made to terminate in *aceæ*, as for example, the names, *Rosaceæ*, *Valerianaceæ*, *Rubiaceæ*, *Caryophyllaceæ* and *Cucurbitaceæ ;* but the names *Compositæ*, *Labiatæ* and *Leguminosæ*, are exceptions. Tribal and sub-tribal names are usually made to terminate in *eæ*, but custom differs somewhat in this regard, and this, as well as the termination *æ*, are often applied to groups of higher rank.

Principal Groups of Plants. We shall treat of the plant sub-kingdom under four great divisions, called Series or Branches. These are the

Thallophyta,
Bryophyta,
Pteridophyta, and
Spermaphyta or *Phanerogamia*.

It cannot be claimed that this is a strictly natural classification ; probably in the present state of our knowledge it is not possible to make one which accurately represents the relations of the lower forms of plant life. The future progress of the science will probably show that the Thallophyta include several groups at least as distinct from each other as the Pteridophyta are from the Phanerogamia. But this confessedly imperfect classification may still serve as a scaffolding with which to build the more perfect structure.

It is beyond the scope of this work to give more than a general view of some of the principal types of plants under each Series.

CHAPTER II.

SERIES I.—THE THALLOPHYTA.

Characteristics of the Series—Classes of Thallophyta.

The name Thallophyta literally means "thallus-plants," and it alludes to the fact that in this Series there is no clear differentiation of the plant-body into root, stem and leaf. It includes a vast number of forms differing widely from each other in structure, appearance and habit, some unicellular and the very simplest and smallest of organisms known, others comparatively complex and of large size. Not even the highest, however, ever possess true roots, though some are provided with root-like, but simpler organs, called *rhizoids*, which serve mainly for anchorage or as holdfasts. A few of the higher forms show some differentiation of stem and leaf, but in no case is this distinction as sharp and clear as we find it in most plants belonging to the higher groups, and in the great majority of cases it is entirely wanting. While also the internal structure in some of the highest forms attains a considerable complexity, there is never a clear differentiation into epidermal, fundamental and fibro-vascular systems of tissue, such as we find in Ferns and Flowering-plants.

Between the highest and lowest forms of the Series, there are various gradations of structure, and these are not always along the same line of development. Among unicellular forms every gradation may be seen between the simplest possible cells and those of the highest degree of complexity, and among multicellular forms, there are those in which the cells are united in the simplest possible way, namely, in a linear series to form filaments, and the cells have so little dependence upon each other that they readily break apart to form distinct organisms. There are those, again, in which the cells are somewhat more intimately united to form cell surfaces or flat expansions consisting of but one layer of cells; and there are still others which by cell-division in three planes, form masses. Among these also many gradations may be observed; some are cell-masses in which the component cells are nearly alike, and there is little difference between different parts of the organism; and there are others in which the component cells become developed into tissue-like groups, each differing from the other, but all closely inter-dependent, and where the plant grows into a definite form with a tendency to the development of distinct organs.

In many members of the Series, the multicellular forms are, as in the higher plants, the product of the division of a single cell; in others, however, the mature plant-body is an aggregate of cells which were originally distinct but have come together to form a community.

The great majority of the plants of the Series are at some period in their development endowed with the power of locomotion. Among the lowest forms the possession of this power may last during a considerable part of the life of the plant, while in the higher forms it is confined to the spore-period, or in some is wanting altogether.

Their habits of life are also various; some are aquatic, others terrestrial; some are chlorophyll-bearing, flourishing only in the light and assimilating mineral matters, while others are chlorophylless, indifferent to light, living as saprophytes or as parasites.

They exhibit great variety also in their modes of reproduction. Among some of the lowest forms no mode is known except that of cell-division; in some others sexual reproduction takes place in its simplest form, namely, by conjugation; in still others it takes place by the simplest mode of fertilization, which consists in the production of oöspores in oögonia, and, lastly, in the highest forms it takes place by that mode of fertilization which results in the production of a fruiting organ, often quite complex in its character, called a sporocarp.

The Series is sub-divided into the following Classes, which will be considered briefly in their order: (1) The *Myxomycetes*, (2) the *Schizophyta*, (3) the *Algæ*, (4) the *Fungi*, and (5) the *Lichenes*.

THALLOPHYTA.

Synoptical View of Principal Subdivisions.

- *Myxomycetes.*
- *Schizophyta* .....
  - Schizomycetes.
  - Cyanophyceæ.
    - Chroöcoccaceæ.
    - Nostocaceæ.
      - Nostoceæ.
      - Oscillatorieæ.
      - Scytonemeæ.
      - Rivularieæ.
- *Algæ* ....
  - Diatomaceæ.
  - Chlorophyceæ.
    - Cœloblasteæ.
    - Protococcaceæ.
    - Volvocineæ.
    - Confervaceæ.
      - Ulvaceæ.
      - Ulothricaceæ.
      - Spheropleæ.
      - Oedogonieæ.
      - Coleochætæ.
    - Conjugatæ.
    - Characeæ.
  - Melanophyceæ or Phæophyceæ
    - Phæosporeæ.
    - Fucaceæ.
  - Florideæ or Rhodophyceæ.
- *Fungi* ....
  - Chytridieæ.
  - Ustilagineæ.
  - Phycomycetes.
    - Zygomycetes.
    - Peronosporeæ.
    - Saprolegnieæ.
  - Ascomycetes.
    - Gymnoascus.
    - Erysypheæ.
    - Tuberaceæ.
    - Pyrenomycetes.
    - Discomycetes.
    - Saccharomycetes.
  - Aecidiomycetes or Uredineæ.
  - Basidiomycetes
    - Tremellineæ.
    - Gasteromycetes.
      - Lycoperdaceæ.
      - Hymenogastreæ.
      - Nidularieæ.
      - Phalloideæ.
    - Hymenomycetes.
      - Thelephoreæ.
      - Clavarieæ.
      - Hydneæ.
      - Polyporeæ.
      - Agaricineæ.
- *Lichenes* ....
  - Homoiomerous Lichenes.
  - Crustaceous "
  - Foliaceous "
  - Fruticose "

CHAPTER III.—THE THALLOPHYTA (CONTINUED).

CLASS I.—THE MYXOMYCETES, OR SLIME-MOULDS.

These are anomalous plants, so near the border-line between the animal and vegetable sub-kingdoms, that some have regarded them as belonging to the one, and some to the other. Naturalists are not even yet fully agreed as to where they belong, but the preponderance of evidence is in favor of regarding them as plants. They are, however, so anomalous in their characters—so different from other plants,—that it is deemed best to put them in a class by themselves. They are not uncommon plants, forming slimy masses amid decaying organic matters; by far the great majority are saprophytes, while a few, as the curious one that causes the disease called "Club-root" on the Cabbage plant, are parasitic. During their vegetative life they avoid the light, and creep about amœba-like among the organic debris on which they feed, but they produce their fructifying organs on the surface. These are sometimes of considerable size, occasionally even as large as a man's closed fist. They vary, however, in size and shape according to the species. When the fructification is ripe, it bursts, and very numerous thick-coated spores are discharged, commonly leaving behind a kind of frame-work which, being usually composed of capillary threads, is called

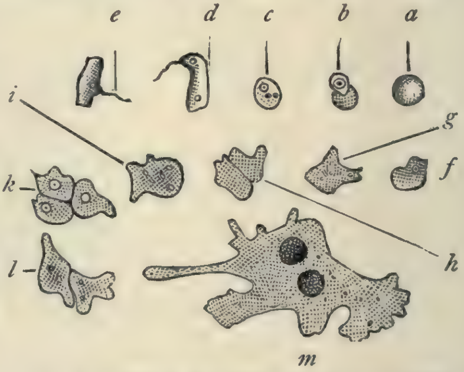


FIG. 466.—Some of the different stages in the development of Physarum album, one of the Myxomycetes. *a*, spore; *b*, protoplasm escaping from spore; *c*, the same when free from the enclosing membrane; *d*, and *e*, after a cilium has been acquired; *f* and *g*, after loss of cilium; *h*, *i*, *k*, *l*, coalescence of amœboid bodies; *m*, a small plasmodium resulting from the coalescence of many amœboid bodies. After Cienowski, from De Bary's "Mycetozoa."

a *capillitium.* When the spores germinate, the protoplasm escapes and moves about, sometimes at first by means of cilia, and then, losing their cilia, by amœboid movements; more commonly, however, the movements are amœba-like from the very start. The moving particles, after growing considerably, divide, the movements in the meantime continuing. After a while, however, two or more of them come together, and the mass thus formed attracts other of the particles, which move toward it and unite with it, forming a colony of considerable size. The colony then sooner or later begins to develop its fructification. But before the fructifying period arrives, if the weather becomes dry and the conditions are not suitable for vegetative growth, the plants become motionless, shrink into compact and more or less rounded forms, secrete a tough enclosing membrane, and are then able to stand desiccation. When favorable conditions for growth return, the protoplasm escapes from its enclosure and resumes its activity.

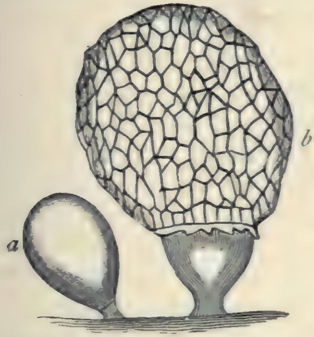


FIG. 467.—Sporangia of another species of Myxomycetes, Arcyria incarnata. *a*, ripe sporangium before dehiscence; *b*, after dehiscence and the dispersion of the spores, show- the net-work of the capillitium. Also after De Bary.

No sexual reproduction is known in these plants, for there is good reason for believing that the union which takes place between the amœboid particles previous to fructification, is not a sexual phenomenon, but purely a vegetative one analogous to that which takes place in many Fungi and some Algæ.

Some of the different stages in the development of one of these plants are represented in Fig. 466. Fig. 467 represents the sporangia of another species.

CHAPTER IV.—THE THALLOPHYTA (CONTINUED).

CLASS II.—THE SCHIZOPHYTA, OR FISSION PLANTS.

These are also very low forms of plant-life, being exceedingly simple in structure, and always minute, some of them being the smallest of known organisms. They are mostly unicellular, or if consisting of cell-aggregates, as is sometimes the case, the cells are united in a simple way, and have very little dependence upon each other. Some possess chlorophyll along with blue coloring matter, and assimilate inorganic food-materials, but many are destitute of chlorophyll, and are either saprophytic or parasitic.

The chlorophyll forms are usually of larger size and better developed than the chlorophylless ones. A few of the former show a slight differentiation of cells, and rarely some of them produce motile or swarm-spores; none, however, of the entire class are known to reproduce sexually, the mode of increase in all of them being mainly by fission, though some also multiply by some other form of cell-division. Most of them are endowed with the power of locomotion, and this may be by means of cilia, or it may be produced by bending from side to side when the cells are united in chains; or, lastly, the cells may be arranged in the form of a spiral, which combines with a progressive motion one of rotation upon its axis, like the motion of a screw when driven into a board.

The class is divided into two sub-classes:

The *Schizomycetes* and the *Cyanophyceæ.*

THE SCHIZOMYCETES.

The term is compounded of two Greek words, meaning literally "fission-fungi," in allusion to the way these plants increase, by fission, and to their fungus-like habits. They are commonly known as Bacteria, and are at once the most abundant and the most minute of organisms. The largest of them are not more than the one ten-thousandth of an inch in diameter, and the smallest not more than one-tenth that size. It requires for their study, therefore, the highest and best powers of the microscope.

They are all chlorophylless organisms, with nearly transparent cell-contents. In all putrefying fluids, or solutions that contain decaying organic matters, they swarm in myriads. They are, in fact, the inciting cause of putrefaction. By their agency also milk sours, wine is converted into vinegar, and many other important fermentations take place. So far as animal life is concerned, some of the species are harmless or perhaps even beneficial, while others are the source of some of the most dreaded and most fatal of diseases. Chicken cholera, splenic fever, small-pox, diphtheria and leprosy are diseases of this class. A peculiar interest, therefore, attaches to the study of these organisms.

The cells agree in having mostly rigid, transparent walls and colorless cell-contents, but different species differ considerably in form, size and in conditions and habits of growth. Their usual mode of increase is by fission, but they also produce very minute spores by internal cell-formation. In some species the cells, after fission, immediately become independent; in others they remain united for a time to form filaments or chains of various length.

Many of the species, in some stage of their development, have the habit of secreting a jelly and increasing rapidly by fission, forming large gelatinous colonies. These are called *zoöglœa*-masses. The "mother-of-vinegar" and the so-called "blood-rain," consisting of red gelatinous spots, often found on putrefying bread, are illustrations.

Most of the species have both their quiescent and their motile stages of development.

There is no group of plants in which it is at present so difficult to define the limits of species. It is difficult to classify them by their forms, because these, under certain conditions, have been found to change into others quite different, and a similar objection applies to classifying them according to their physiological effects, since it has been found that, in some instances at least, an innocent species may, by cultivation, be changed to one of great virulence and, *vice versa*, a virulent one may be changed to one that is harmless. For practical purposes, however, Cohn's classification, based on the forms, is as convenient as any. According to this author there are four principal groups, the Micrococcus or spherical forms, the Bacterium or rod-like forms, the Bacillus or filiform forms, and the Spirillum or coiled forms. In the Micrococcus genus the cells are exceedingly minute, rounded and either distinct or united loosely like a string of beads. In the genus Bacterium, the cells are also independent or very loosely united and cylindrical in shape with rounded ends, which sometimes, at least, are provided with cilia. Under the Bacillus-group several genera are distinguished according to the shape of the filaments. The Bacillus proper consists of short, straight but slender filaments; the genus Leptothrix have the filaments slender and long; in the genus Beggiatoa the filaments are thicker and long; in the genus Cladothrix the filaments are branching; and in the genus Crenothrix they are simple but enclosed in a gelatinous or mucilaginous envelope. In the Spirillum group, the genus Spirillum consists of filaments which have but few coils, but the coils are rigid; in the genus Spirochæte the filaments are slender, many-coiled and not rigid.

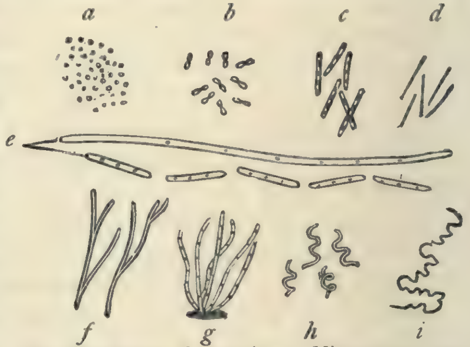


FIG. 468.—Forms of Bacteria. *a*, Micrococcus, magnified about 1,800 diameters; *b*, Bacterium termo, magnified about 1,500 diameters; *c*, Bacillus tuberculosis, magnified about 1,800 diameters; *d*, Leptothrix buccalis, magnified about 800 diameters; *e*, Beggiatoa alba, magnified about 600 diameters; *f*, Cladothrix dichotoma, magnified about 1,000 diameters; *g*, Crenothrix Kühniana, magnified about 300 diameters; *h*, Spirillum undulu, magnified about 800 diameters; *i*, Spirochæte plicatilis, magnified about 600 diameters.

Some idea of the more prominent types may be obtained from the illustrations, Fig. 468.

THE CYANOPHYCEÆ.

The term is derived from two Greek words, which literally mean "blue-green sea-weed." The plants are mostly inhabitants of fresh water, though a few are marine, and they contain, in addition to chlorophyll, a blue, and also sometimes brownish or reddish, coloring matters in their cells. In some species the cells are distinct; in others they are more or less united into chains or filaments. There are two orders, the *Chroococcaceæ* and the *Nostocaceæ*.

The **Chroococcaceæ** occur either as isolated cells, or, more commonly, in groups, imbedded in a gelatinous matrix. The cells of the mass are, however, never closely connected. Glœocapsa may be taken as an illustration of the group. Like many of its congeners, it is found growing on damp rocks adjacent to springs, where they form slimy masses. The cell-walls swell and become converted into a stratified jelly, and in the mean time the cells multiply by fission in different planes within the jelly, forming masses of various sizes. The plant and the way it multiplies are illustrated in Fig. 469. Other forms, as Merismopedia, produce by division in one plane symmetrical, tabular families, consisting of four, eight, sixteen, thirty-two or sixty-four rounded cells, held together by a firm gelatinous matrix.

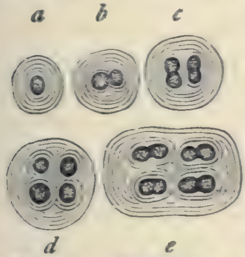


FIG. 469.—Glœocapsa. *a*, fully developed cell with gelatinous, greatly thickened and stratified cell-wall; *b*, *c*, *d*, *e*, illustrate mode of multiplication. Magnified about 150 diameters.

It is believed by many that most of the forms of this group are but stages in the development of higher forms.

The **Nostocaceæ** include a number of genera, the most important of which are the Nostocs, Oscillatorias, Scytonemas and Rivularias.

The *Nostocs* occur as greenish or brownish, tough gelatinous masses, some species of which are as large as a hen's egg, or even larger. They are common in ponds or slow streams, or on the damp ground bordering rivers, swamps and lakes. If a section be made of one of these masses and examined microscopically, it will be seen to contain, imbedded in the jelly, very numerous serpentine threads, composed of spherical cells loosely attached to each other in chains or moniliform rows. At intervals in the chain of cells occur larger cells, called *heterocysts*. Fig. 470 shows one of these threads highly magnified.

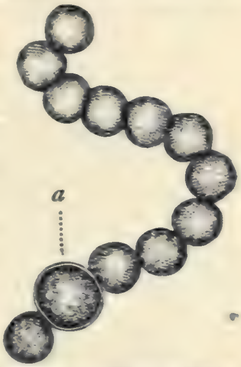


FIG. 470.—Filament of Nostoc magnified about 800 diameters. *a*, a heterocyst.

The *Oscillatorieæ* are blue-green or brownish-green filamentous organisms, found abundantly in filthy ditches and ponds. The filaments are slender, usually somewhat coiled, and composed of compactly arranged disc-like cells, which are all alike. These are separated from each other by delicate transverse partitions. The filaments are commonly agglomerated in masses, and each possesses a peculiar writhing or oscillating motion. It is to this that the name, Oscillatoria, is due. Frequently the filaments break up transversely into short segments, each of which, by cell-division in a transverse direction, becomes a new filament. This is the only mode of reproduction that has been observed in the group. Fig. 471 represents a portion of one of the filaments.

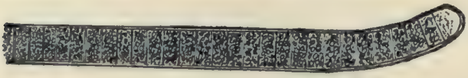


FIG. 471.—Portion of filament of Oscillatoria, magnified about 1,000 diameters.

The *Scytonemeæ* are also filamentous greenish or brownish plants, but they branch in a peculiar manner, as shown in the illustration, Fig. 472. Moreover, there are often more than one row of cells side by side, particularly in older filaments, and the cells are enclosed in a thick gelatinous envelope. Besides increasing by ordinary cell-division, they produce heterocysts and asexual spores.

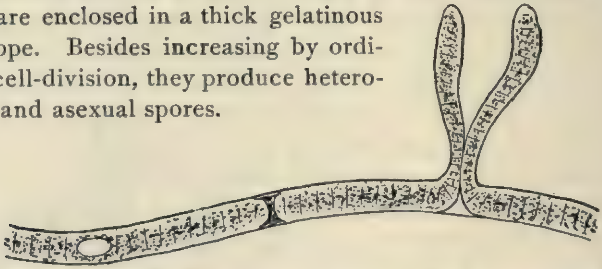


FIG. 472.—Portion of filament of Scytonema Nægellii, magnified 250 diameters.

The *Rivularieæ* occur as small roundish gelatinous masses of radiating, somewhat branching filaments, each tipped with a transparent hair. At the opposite or basal end of the filament is a large rounded cell, the heterocyst. The plants, or rather colonies, either float in the water or are attached to water-weeds, submerged rocks, etc. Fig. 473 shows a filament of one of the species.

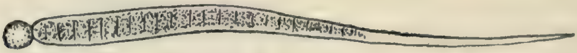


FIG. 473.—Filament of Rivularia dura, magnified about 500 diameters.

CHAPTER V.—THE THALLOPHYTA (CONTINUED).

CLASS III.—THE ALGÆ.

THE DIATOMACEÆ AND THE CHLOROPHYCEÆ.

Under the Algæ are included that vast host of Thallophytic plants which contain chlorophyll, except the Cyanophyceæ, which have already been treated, and the Lichenes, which consist of chlorophyll-bearing, associated with chlorophylless Thallophytes. The group is divided into four sub-classes, the *Diatomaceæ*, the *Chlorophyceæ*, the *Melanophyceæ* and the *Florideæ.*

THE DIATOMACEÆ.

The Diatomaceæ are so peculiar in their structure that some botanists have relegated them to a class by themselves. They are all in reality unicellular, though sometimes united in colonies, and all are microscopic in size. They possess chlorophyll-plates in their protoplasm, but the green color is more or less obscured by the presence of a peculiar brown coloring matter. They are also endowed with the power of locomotion, the movement being a gliding one, but how it is accomplished is not yet certainly known.

The great distinguishing feature of the group, however, is the peculiar structure of the enclosing membrane. This is a silicious box consisting of two pieces fitting one into the other, like the parts of a common band-box. The two valves, as the parts of the box are called, are usually alike, excepting that one is a trifle larger than the other, so as to fit over it, and both are beautifully and often very delicately and regularly sculptured.

Not less interesting and strange is their mode of reproduction. This takes place by fission, and in many species also sexually by conjugation, but the processes are peculiar. When the process of fission begins, the valves separate slightly from each other, the protoplasm divides into two portions, and each secretes for itself a new valve to fit within the old one that lies adjacent to it, and the plants thus become independent.

It is evident that, as successive divisions take place, there will be a gradual reduction in the size of the plants, since the rigid valves once formed are not capable of expansion ; so the process only goes on for a certain number of generations, when it is interrupted by the formation of what is called an *auxospore.* This may be formed asexually, simply by rejuvenation or the escape of the protoplasm from the old valves, or it may be the result of the conjugation of the protoplasm of two plants and the discarding of the old valves. In either case the new valves which are secreted are of the same size as those with which the first generation started.

Diatoms are exceedingly abundant plants, both in individuals and in species, being found in nearly all waters, both salt and fresh, that are reasonably free from putrid matters. They occur in the tropics, in springs where waters are so hot that few other forms of life are able to survive, and in the ice-cold waters of the polar seas. Their shapes are also exceedingly various. Some of the different forms are represented in Figs. 474 to 478, inclusive.

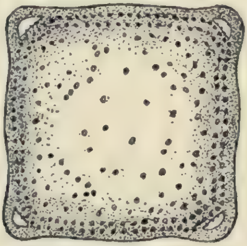


FIG. 476.

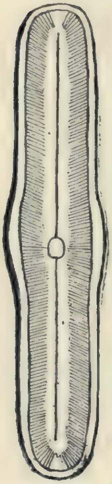


FIG. 474.

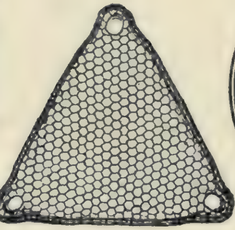


FIG. 477.

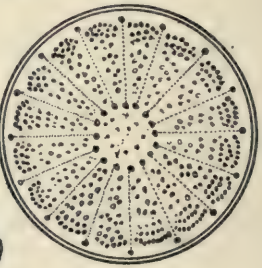


FIG. 478.

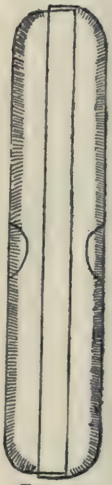


FIG. 475.

FIG. 474.—Side view of valves of Pinnularia dactylus, magnified about 300 diameters.
FIG. 475.—Front view of the same diameter, showing the way the valves fit together.
FIG. 476.—Valve of Triceratium intermedium, magnified about 500 diameters. After Grove and Sturt.
FIG. 477.—Triceratium favus, magnified about 150 diameters.
FIG. 478.—Cosmiodiscus Normanianus, magnified about 600 diameters. After Grove & Sturt.

THE CHLOROPHYCEÆ.

This group includes quite a variety of forms, some simple in their structure, others comparatively complex. None of them possess a soluble blue or brown coloring matter in the cells, though the spores of some, when ripe, have portions of their chlorophyll modified into a substance chemically similar to the latter substance, but having a red color. Most of the forms reproduce not only asexually by some mode of cell-division, but also sexually, either by conjugation or by the production of oöspores. In all of the groups gradations may be observed between these two modes. The sub-class is divided into six orders: the *Cœloblasteæ* or Siphoneæ, the *Protococcaceæ*, the *Volvocineæ*, the *Confervoideæ*, the *Conjugatæ* and the *Characeæ*.

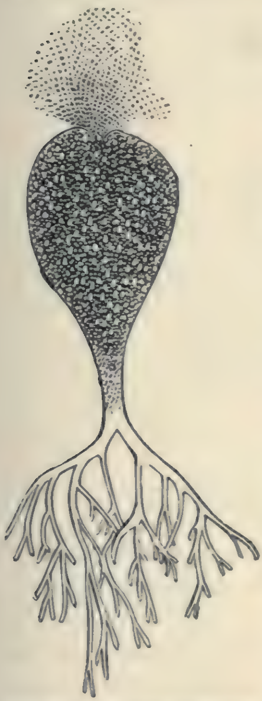


FIG. 479. — Botrydium granulatum, in the act of discharging its zoöspores. Magnified about 20 diameters. After Wolle.

The Cœloblasteæ. These include both marine and fresh-water forms. One of their most distinctive characteristics is the fact that, though often complex in form and attaining a considerable size, they are not divided into cells; each plant, in fact, may be regarded as a single highly elaborated cell. In a few species no sexual reproduction is known, in others it takes place by conjugating zoöspores, and in still others, by fertilization and the production of oöspores.

Among the simplest forms of the group are the *Botrydiums*, one of which is represented in Fig. 479. The lower portion forms dichotomously branching root-like bodies or rhizoids, which penetrate the mud and serve for anchorage, while the balloon-shaped upper portion rises into the water above. This is filled with granular protoplasm and contains much chlorophyll.

The plants multiply in several different ways. When the ponds in which they grow begin to dry up, the protoplasm descends into the rhizoids and there breaks up to form numerous rounded cells which are capable of enduring desiccation. When favorable conditions return, these either germinate and form new plants or immediately develop into sporangia.

The upper or bulbous part of the plant, when mature, also becomes a sporangium. The spores discharged by this may be of two kinds; one kind has but one cilium, and after moving about for a while it comes to rest and develops immediately into a new plant; the other possesses two cilia and conjugates with another similar spore forming a zygospore, and this, sooner or later, develops into a new plant. The figure shows the plant in the act of discharging its zoöspores.

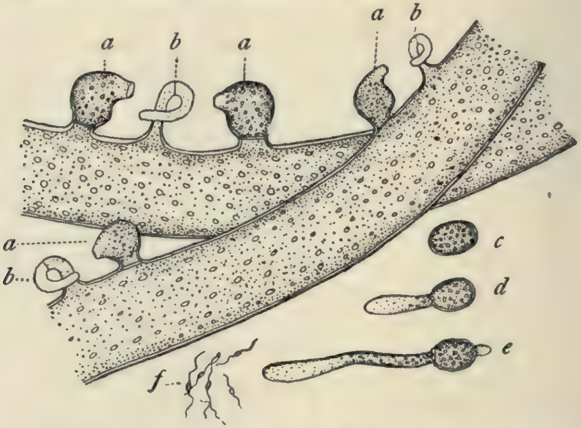


FIG. 480.—Portions of fertile filaments of Vaucheria sessilis, showing mode of sexual reproduction. *a*, *a*, *a*, *a*, oögonia; *b*, *b*, *b*, antheridia; *c*, oöspore; *d*, *e*, germinating oöspores; *f*, antherozoids. Magnified about 175 diameters.

The Vaucherias, or Green Felts, form another group of the Cœloblasteæ. They occur as dense, felt-like masses in wet soil, on dripping rocks adjacent to springs, and in other similar situations.

The individual filaments in some species attain a length of eight or ten inches. They root in the mud by means of rhizoids similar to those of Botrydium, and the filaments are more or less branching. Besides chlorophyll-bodies, they contain numerous oil-globules distributed through the interior of the tubes.

They reproduce asexually either by the separation of the ends of some of the branches, or by the escape of swarm-spores clothed with cilia.

Their mode of sexual reproduction is illustrated in Fig. 480. The oögonium, it will be seen, is an oval body borne laterally on the filament, and cut off from it by a partition. The antheridal branch, which is located adjacent to it, is slender and curved, a transverse partition is formed near its middle, and in the terminal cell thus produced are developed an immense number of very minute, ciliated antherozoids, which are discharged by a rupture of the cell-walls. Some of them find their way through the terminal opening of an oögonium, and fertilize the contained oösphere. It then develops into an oöspore, which, after resting until the succeeding spring, germinates.

The species of Bryopsis ; the Acetabularias, curious umbrella-shaped marine forms ; and the Caulerpas, sea-shore plants, sometimes attaining a length of several yards, and having rhizoids, creeping stems and leaf-like branches, looking wonderfully like the much more highly organized multicellular plants, which have roots, stems and leaves, are also classed with the Cœloblasteæ.

The Protococcaceæ include a number of forms of fresh-water algæ, some of which occur as isolated cells, while others consist of cells once distinct, which have united to form cell-colonies. These colonies have a definite shape peculiar to the species, and are called *cœnobia*. In the vegetative form the plants are not endowed with the power of locomotion, and in this respect differ from the Volvocineæ. Cell-division occurs usually by internal cell-formation, and the cells always at first become distinct from each other, though they sometimes unite afterwards, as we have seen, to form cœnobia. They reproduce asexually by means of zoöspores, and most of them also sexually by the conjugation of zoöspores of smaller size.

Some of the unicellular forms live in the interior of other plants, though not parasitically. One of these, called Chlorochytrium Lemnæ, grows in the intercellular spaces of the thallus of the common Duck-weed, Lemna trisulca.

Among the forms which produce Cœnobia are the Pediastrums and Hydrodictyon. The former are free microscopic forms, found abundantly in most fresh waters. The shapes of the cœnobia are roundish or stellately discoidal. Usually the central cells of the disc are polygonal, and those constituting the outer circle are commonly two-lobed.

The contents of the cells after a time break up into small rounded masses, which acquire cilia, and move about for a time on the interior of the cell. They then break through the membrane and escape ; they soon come to rest, however, and divide again and again to form a colony, which at first consists of loosely and irregularly aggregated masses of cells. The colony now becomes enclosed in a mass of jelly secreted by its members, and then the latter arrange themselves in one plane to form such a cœnobium as that already described. Some of the cells of the cœnobia have also been observed to produce another kind of ciliated spore much more minute. There is reason to believe that these conjugate, but the process has not been actually observed. Fig. 481 represents the mature cœnobium of one of these plants.

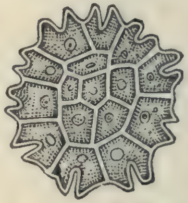


FIG. 481.—Pediastrium Boryanum, magnified 350 diamters.

The Hydrodicyon, or Water-net, is an interesting fresh-water alga, not uncommon in ponds, lakes and slow streams. In the mature form of the plant the cells are arranged to form a quite regular net-work, which takes the shape of an elongated purse or bag, often attaining a length of eight or ten inches. Asexual reproduction takes place as follows : In the interior of some of the cells composing the mature net, the protoplasm breaks up and forms a multitude of ciliated spores, sometimes as many as 15,000 to 20,000. These move about actively for a time within the parent cell-walls, and then arrange themselves to form minute new nets, which are finally set free by the rupture or solution of the enclosing walls, and in the course of a few weeks attain a size similar to that of the parent colony.

In the sexual mode, numerous similar, but very much smaller ciliated spores, are formed in some of the mature cells of the colony ; these, instead of arranging themselves to form a reticulum, escape through the mother cell-wall, conjugate in pairs, and after moving about for a time, become quiescent, acquire a thick cell-wall, and after a period of rest, germinate.

Fig. 482, *a*, represents a portion of a mature Water-net not far from the natural size, and *b*, one of the cells greatly enlarged, showing numerous small cells in the interior, in the act of arranging themselves into a net.

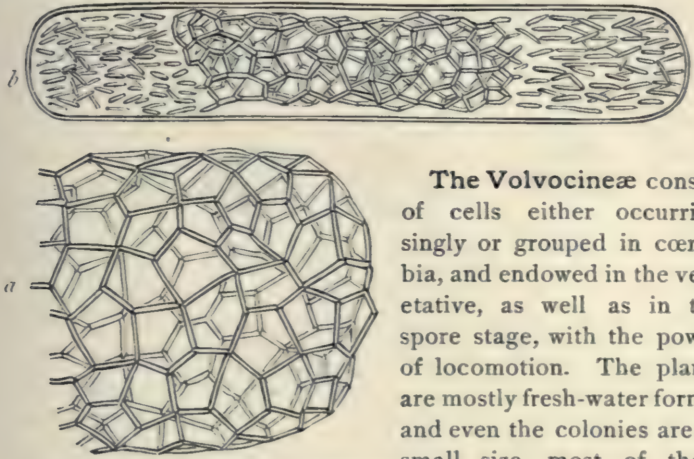


FIG. 482.—The Hydrodictyon or Water-net. *a*, portion of colony nearly natural size ; *b*, one of the cells of the colony greatly enlarged, showing in the interior minute cells arranging themselves to form a reticulum.

The Volvocineæ consist of cells either occurring singly or grouped in cœnobia, and endowed in the vegetative, as well as in the spore stage, with the power of locomotion. The plants are mostly fresh-water forms, and even the colonies are of small size, most of them microscopic. They multiply asexually by cell-division. The mode of sexual reproduction in some is by the conjugation of swarm-spores, while in the higher forms of the group, the process is that of fertilization, the germ-cell being of larger size and quiescent, while the fertilizing cell is small and provided with cilia.

Among the unicellular forms are Chlamydomonas and Euglena. Euglena viridis may be taken to illustrate this section of the group. The cells are somewhat fusiform in shape, but capable of spontaneously changing their form. At the anterior end is a long flagellum, by which the cell is propelled, and near the base of the flagellum a red spot, commonly called the "eye-spot." Increase, during the vegetative period, takes place by fission in a longitudinal direction. After a period of activity of longer or shorter duration, the cells come to rest, shrink into a round form and acquire a firm integument. On the recurrence of conditions suitable for growth, the cells divide repeatedly, and finally resume the active, flagellate form. See Fig. 483. Sexual reproduction has not yet been observed in this genus, but in Chlamydomonas, a related one, the small cells produced by the division of the parent cell, have been observed to conjugate.

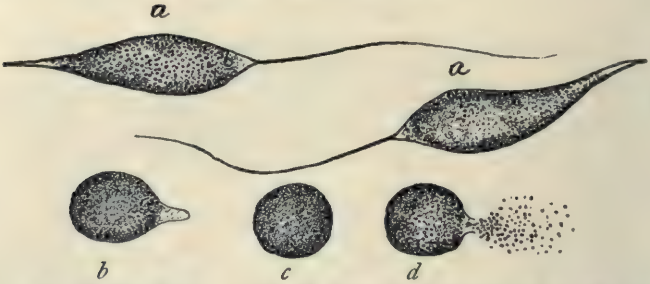


FIG. 483.—Euglena viridis. *a, a,* motile forms, each provided with a long flagellum and an "eye-spot ; *b,* one of the cells passing into the encysted stage ; *c,* encysted form; *d,* encysted form discharging minute swarm-spores.

Pandorina and Volvox may be taken to illustrate the forms which produce cœnobia. In Pandorina the cœnobia consist of sixteen, or less commonly of eight or thirty-two cells, crowded into a spheroidal mass, and surrounded by a transparent gelatinous envelope. Each cell possesses two cilia which project through the envelope and by which the colony is propelled with a rolling motion through the water. Asexual reproduction takes place by the formation of sixteen new cells in the interior of each cell of the colony. These young colonies after a time escape from the parent cells and form independent cœnobia.

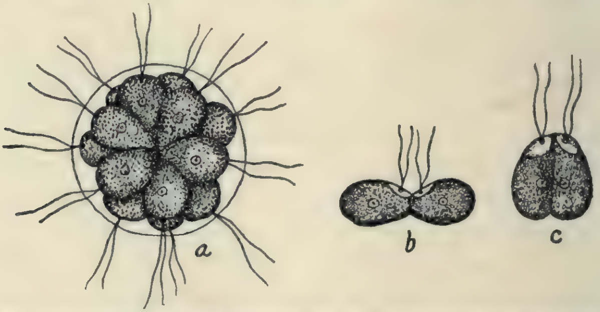


FIG. 484.—Pandorina Morum, a fresh-water alga. *a,* colony of sixteen cells, each provided with a pair of cilia, by means of which the whole colony moves through the water with a rolling motion; *b,* two zoöspores of the same plant in the act of conjugation; *c,* the process nearly completed. Magnified about 150 diameters.

In the sexual reproduction, cell-division takes place as before, but the cells which are formed escape from their enclosure by the softening of the gelatinous membrane and move about individually by means of their cilia, finally conjugating and forming zygospores which, when mature, acquire a brownish-red color. These after a period of rest germinate, produce a few swarmpores, and these in turn divide to form colonies of sixteen. See Fig. 484.

Volvox globator is a more highly developed but similar plant also common in our fresh waters. When mature it has a diameter of about half that of an ordinary pin-head, and the cells composing it, which are quite numerous, are so arranged as to form a hollow, spherical colony. The cells are chlorophyll-bearing and imbedded in a tough, gelatinous, transparent membrane, which forms the wall of the sphere; they are ordinarily connected with each other by threads of protoplasm, which form a delicate network over the surface, and each cell is provided with a pair of cilia which project beyond the enveloping membrane, and by their rhythmic vibrations communicate a rolling motion to the cœnobium.

Asexual reproduction takes place as follows: Some of the vegetative cells, which are of larger size than the rest, escape from the envelope into the interior of the sphere, lose their cilia, and by cell-division form miniature colonies similar to the parent one. Often two or three of these colonies can be seen within the parent cœnobium. These continue to grow until the walls of the colony can no longer contain them, when by its rupturing, they escape and become independent.

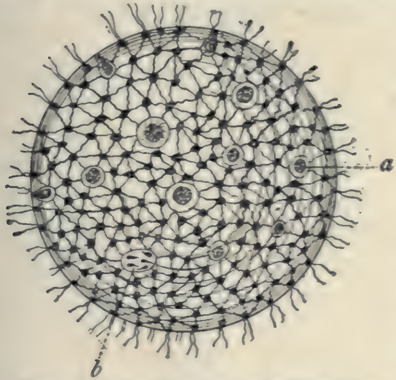


FIG. 485.—Volvox globator, magnified about 75 diameters. *a*, one of the oögonia; *b*, one of the antheridia from which most of the antherozoids have escaped.

In the sexual reproduction, which occurs toward the close of the season, some of the cells develop into oöspheres, and others into antheridia, containing numerous antherozoids. The former become larger than the vegetative cells, and escape into the interior of the colony. The antheridia also increase considerably in size, their protoplasm divides into a multitude of small cells, which become filled with an orange-colored endochrome, acquire cilia, and finally also escape into the interior of the colony, when they swarm about the oöspheres, penetrate into their protoplasm and fertilize them. After the resulting oöspores have matured, the walls of the parent colony dissolve away and the spores are set free. Fig. 485 represents a fertile colony of this species.

The Confervaceæ. The plants of this group are all chlorophyll-green algæ, chiefly inhabiting fresh waters, and most of them are either filamentous or they form a flattened thallus, consisting of a single layer, or at most of two layers, of cells. In a few forms the filaments are branching, in a few others, adjacent filaments anastomose, and in some, the component cells secrete a mucilage and become separated from each other, forming a mucilaginous mass, in which the cells multiply by division.

Most of the forms reproduce by asexual zoöspores, many reproduce sexually by means of conjugating zoöpores, still others produce oögonia containing one or more oöspheres, and antheridia which produce ciliated antherozoids; but there are still others whose life-histories have not yet been traced out.

The order includes a large number of forms, grouped mainly under the following families: the Ulvaceæ, the Ulothricaceæ, the Spheropleæ, the Oedogonieæ and the Coleochætæ.

The Ulvas, so common in marine estuaries and salt marshes, are often called Sea-lettuce, from the shape of the bright-green fronds, which consist of thin, flattened or crispate membranous expansions, often several inches in breadth, and attached to stones, shells, etc. The fronds consist of two strata of cells, and increase in size by cell division in two planes. In the early stages of their development, however, they are filamentous, but afterward, by cell-division in two planes, become laterally expanded. After a time they produce bi-ciliated or sometimes quadri-ciliated swarm-spores. In one species at least, Ulva Lactuca, some of the spores have been observed to come together by their ciliated ends and fuse into an oval mass, forming a zygospore. This after a time divides and forms a colony of individual cells, each of which is capable of developing into the mature form of the plant. In this case there is no evident distinction in form and size between the spores which conjugate and those of the asexual generation. Fig. 486 represents one of these plants.

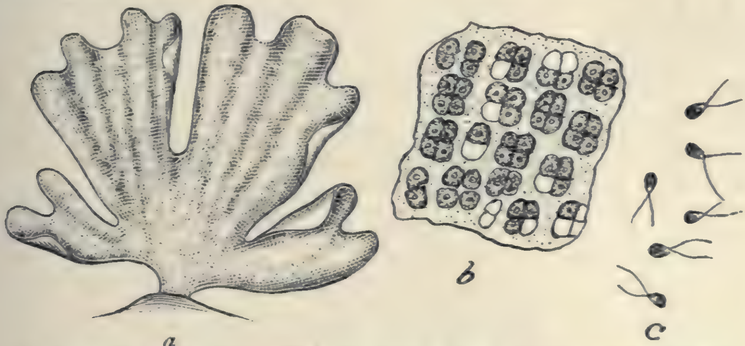


FIG. 486.—*a*, Ulva Lactuca, frond about natural size ; *b*, portion of frond magnified, showing arrangement of cells ; the unshaded ones are those from which zoöspores have escaped ; *c*, biciliated zoöspores.

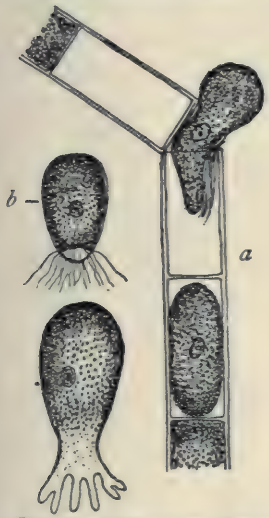


FIG. 487.—Oedogonium, showing asexual modes of reproduction. *a*, portion of filament with the protoplasm escaping to become a free, ciliated cell, *b*; *c*, the same cell throwing out rhizoids. Magnified about 250 diameters.

The *Oedogoniums* are filamentous, mostly unbranching fresh-water algæ, whose cells are densely packed with chlorophyll-bodies. They are not uncommon in ponds, ditches and slow streams, where they occur in patches, attached by means of root-like processes to sticks, stones, the stems of aquatic plants, etc. There are a large number of species, some of them monocarpous, others diœcious. They reproduce asexually, not only by the transverse fission of their cells, but by the production of zoöspores. In the latter process, the protoplasm of the cell becomes aggregated into a rounded or oblong mass, acquires a fringe of cilia at one end, escapes from the cell-wall, and moves through the water for a time, but finally comes to rest, sends out from one end root-like processes, attaches itself to some object in the water, and develops into a filament. See Fig. 487.

It not infrequently happens, also, that soon after the germination of the spore, rejuvenescence takes place ; that is, the wall ruptures and the protoplasm escapes to form a new cell, which sooner or later again germinates. See Fig. 488.

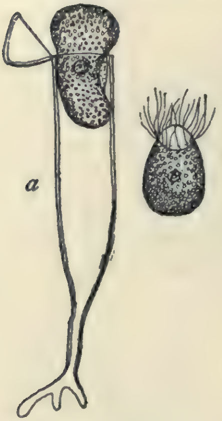


Fig. 488.—*a*, young plant of Oedogonium reproducing itself by rejuvenescence ; *b*, the escaped protoplasm after it has acquired cilia. Magnified about 250 diameters.

In the sexual reproduction, one or more of the cells of the filament become greatly enlarged to form oögonia. When mature, an opening or pore is formed in their walls and antherozoids, produced either on another filament or in other cells of the same filament, find their way through the openings and fertilize them. This is the common mode ; in other cases, however, small ciliated cells, called androspores, are produced either in a male filament, or in other cells of the same filament that produces the oögonia ; but these, instead of directly fertilizing the latter, become attached by a root-like process to it or near it, lose their cilia, grow into a short filament, and finally the terminal cell of the latter ruptures, setting free a minute antherozoid, which penetrates the aperture of the oögonium and fertilizes the oösphore. See Figure 489.

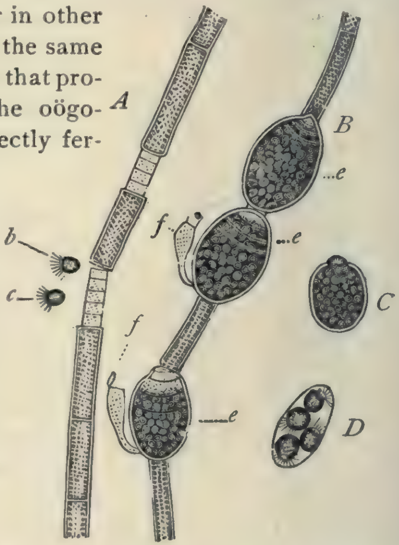


Fig. 489.—Oedogonium ciliatum, showing mode of sexual reproduction. *A*, portion of male filament producing androspores *b* and *c*. *B*, portion of female filament producing oögonia *e*, *e*, *e* ; *f*, *f*, male plants produced from androspores, which have germinated on the sides of two of the oögonia, and are each discharging a minute antherozoid. The filament has partially broken apart, leaving an opening in the top of the lower oögonium, so that the antherozoid may enter. This end of the oögonium is filled with mucilage, which slightly protrudes from the opening. *C*, a ripe oögonium, which has separated from the filament. *D*, represents the production of four ciliated spores from the protoplasm of the germinating oöspore.

After fertilization, the oöspore acquires a thick cell-wall, and in ripening changes to a brown color. The oögonium, with the ripened oöspore still enclosed within its walls, now separates from the filament which bore it, and the spore, after a period of rest, germinates. It does not, however, immediately develop into a filament, but the protoplasm of the spore first escapes into the water enclosed within a mucilage, then the protoplasm divides and forms four ciliated cells. These escape from the mucilaginous envelope, and, after moving about for a while, come to rest, and each develops into a filament.

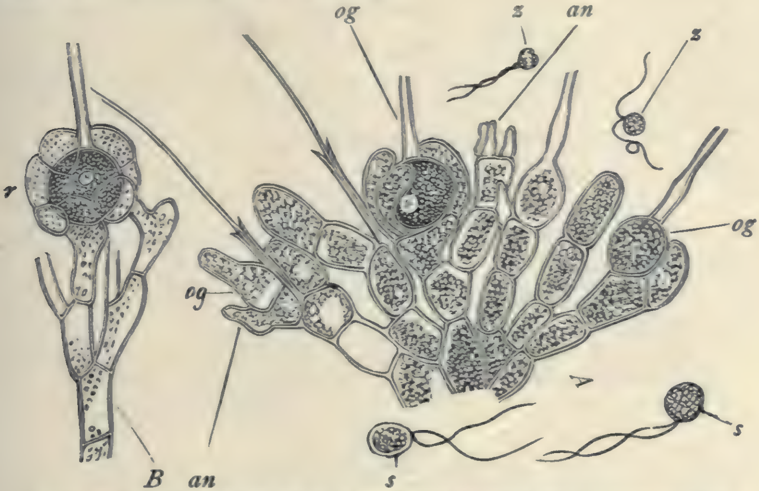


FIG. 490.—*A*, part of fertile thallus of Coleochæte pulvinata (magnified 350 diameters). *og*, *og*, *og*, oögonia in various stages of development; *an*, *an*, antheridia; *z*, *z*. antherozoids; *s*, *s*, swarm-spores; *B*, ripe oögonium in its cellular rind, *r*. After Pringsheim, from Sachs' Botany.

The Coleochæte. We may take Coleochæte pulvinata to illustrate this group. It occurs as small rounded, dark-green or olive-green masses, from $\frac{1}{12}$ to $\frac{1}{2}$ an inch in diameter, attached to stones, sticks or water-weeds in calcareous spring-waters. Each mass consists of a number of articulated, branching filaments, the cells composing which are oblong, narrower at the basal end, more or less dilated anteriorly, and often provided with a transparent hair or bristle, which has at its base a kind of sheath.

The plants propagate themselves asexually by means of zoöspores, which may arise from any of the vegetative cells, and sexually by means of oögonia and antheridia. The former are always modified terminal cells of a branch. The cell becomes swollen at the base and elongated into a tube at its apex, and when ready for fertilization, the tube opens and emits a colorless mucilage. The antheridia are small flask-shaped bodies, borne singly, or two or more together, at the ends of other branches, or on adjacent cells. Each of these when ripe emits a single antherozoid. The latter moves about by means of two cilia, and probably finds its way through the mucilage down the tube of the oögonium to the oösphere at its base and fertilizes it. In the course of the ripening of the oögonium, there grows up about it from adjacent cells a cellular rind or protecting sheath. See Fig. 490, *A* and *B*. The ripe oöspore does not immediately develop into the mature form of the plant, but, after a period of rest, first forms swarm-spores, from which the filaments are finally produced.

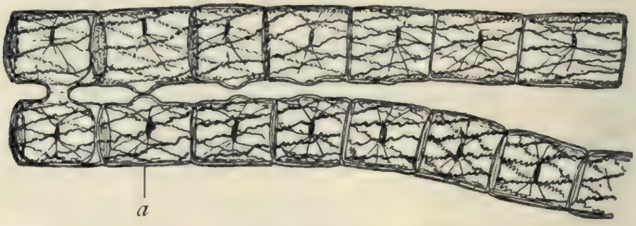


FIG. 491.—Spirogyra maxima in incipient stages of conjugation. *a*, cell-nucleus, fusiform in shape and suspended in the interior of the cell by delicate protoplasmic threads. Magnified about 100 diameters.

The Conjugatæ. This group differs from all other algæ in the peculiarly complex structure of their chlorophyll-bodies; from all, except some of the Diatomaceæ, in their mode of sexual reproduction, which consists in the direct conjugation of ordinary vegetative cells, and from many in not producing swarm-spores. In some of the species the chlorophyll-bodies form plates of definite form and arrangement, in others, star-shaped masses, and in still others, spiral bands. A few of the forms are unicellular, but most of them consist of unbranching filaments. To this group belong a number of genera represented by species common in our fresh waters, most important of which are Mesocarpus, the Spirogyras, the Zygnemas and the Desmids.

The *Spirogyras* are filamentous algæ, very common in ponds and ditches, and they occur in masses of silky, green threads which sometimes attain a length of six or eight inches. The name Spirogyra was given in allusion to the fact that the chlorophyll-bodies form spiral bands winding around the cell adjacent to its interior wall. In some species the bands are single, in others there may be two or more. Their modes of fission and conjugation have already been described in Part II. See, also, Fig. 491.

The Zygnemas differ from the Spirogyras in having the chlorophyll-bodies stellate in form and arranged axillary, a pair of them in each cell.

In Mesocarpus and some other related forms the zygospore is not formed within either of the conjugating cells but in the space between them, as shown in Fig. 492.

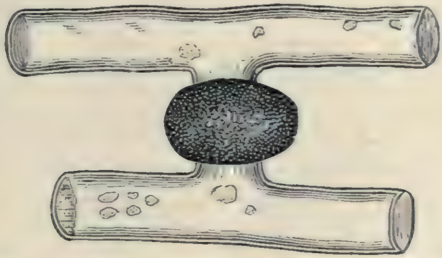


FIG. 492.—Cells of two filaments of Mesocarpus scalaris with zygospore formed between them. Magnified about 350 diameters.

The Desmids are found in great abundance and variety in clear, fresh water. They are mostly unicellular, but in some cases are loosely united into filaments. They have firm but not flinty cell-walls, and the cells are usually more or less constricted in the middle; when this is not the case the symmetrical arrangement of the cell contents into two halves is more or less evident. The species are exceedingly numerous, and the semi-cells of many are lobed, spinose, delicately striated or otherwise ornamented.

Asexual reproduction takes place by division along the plane of symmetry between the semi-cells. The new wall thus formed is double, and on each side of it is formed a new semi-cell. When these reach a size about as great as that of the old semi-cells, separation takes place. Each of the new plants thus formed, therefore, consists of an old and a newly-formed semi-cell. This mode of multiplication is illustrated in Fig. 493.

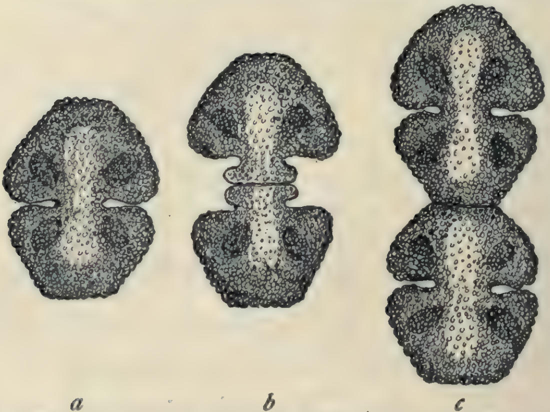


FIG. 493.—Cosmarium Botrytis, a Desmid, showing process of division. *a*, the mature plant; *b*, the plant in an early stage of division, with two new semi-cells forming between the old ones; *c*, the process nearly completed. Magnified about 500 diameters.

Sexual reproduction takes place usually late in the season, and consists in the conjugation of two cells which come together for the purpose. The zygospore differs considerably in appearance in different species. Sometimes it is smooth and spherical, at others warty or tuberculate, and in still others spiny, as in Fig. 494, which illustrates the sexual reproduction of Cosmarium Botrytis.

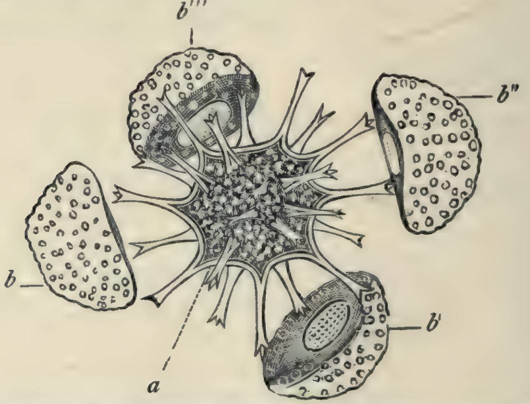


FIG. 494.—Conjugation of Cosmarium Botrytis. *a*, zygospore; *b*, *b'*, *b''* and *b'''*, the empty semi-cells of the two plants. Magnified about 500 diameters.

In Fig. 495 are represented several other forms of Desmids.

The Characeæ. These are submerged fresh-water plants, rooting in the muddy bottoms of ditches, ponds and sluggish streams. They do not possess true roots, but fasten themselves to the mud by means of root-like processes called rhizoids.

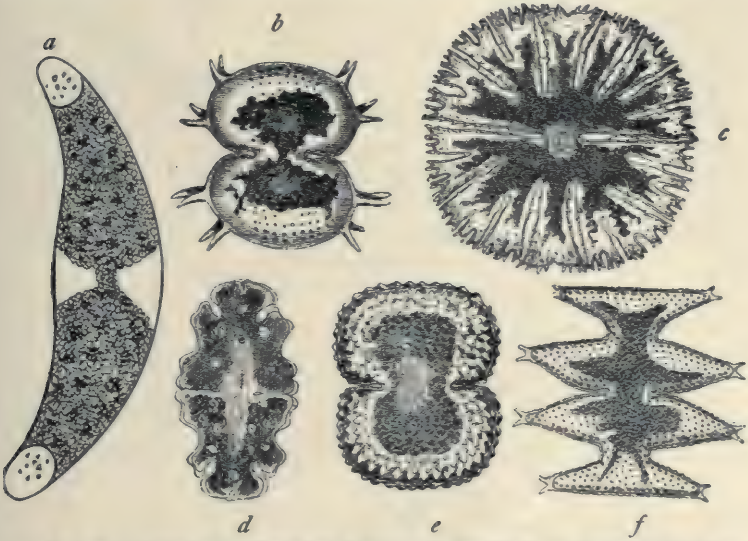


FIG. 495.—Desmids. *a*, Closterium Ehrenbergii, magnified 100 diameters; *b*, Xanthidium fasciculatum, magnified 500 diameters; *c*, Micrasterias radiosa, magnified 200 diameters; *d*, Euastrum elegans, magnified 500 diameters; *e*, Cosmarium pardalis (?), magnified 500 diameters; *f*, Micrasterias pinnatifida, magnified about 400 diameters.

They bear at intervals on the slender stems whorled appendages, which may be taken to represent leaves, and in the axils of these, branches occur. See Fig. 496. The stem increases in length by the continual division of the apical cell in a transverse direction, and by the growth in length of some of the cells thus produced. The cells resulting from this division are alternately nodal and internodal cells. The latter become greatly elongated, sometimes several inches in length, but do not again divide. Not so, however, with the nodal cells. These increase but little in length, but divide longitudinally to produce the lateral appendages,—leaves, stems and fruiting organs. From them also originates the cellular cortex which in the genus Chara, but not in the related genus Nitella, covers the internodal cell and keeps pace with its growth. In this mode of growth, as well as in the structure of their fruiting organs, the Characeæ are peculiar among plants. In complexity of structure, also, they rank highest among Algæ. The plants are abundant in species, and are widely distributed over the world, but they all belong to the two genera already mentioned. Some are of small size, only one or two inches high; other species attain the height of two or three feet. Nearly all are gregarious in their habits.

They agree with the Conjugatæ in not producing swarm-spores, their asexual reproduction being by means of tuber-like structures borne on the subterranean parts, or by peculiar branches which form rhizoids on their basal nodes and become separated from the parent plant.

They reproduce sexually by means of oögonia and antheridia, both of which have interesting peculiarities in their structure. These organs are, in some species, both borne on the same plant; in others, on different individuals; they occur at the nodes, and may be regarded as modified leaves. The oögonium is at first a single cell, but in the course of its development it divides transversely, and the apical cell becomes enlarged and develops into a germ-cell. This soon becomes covered by a layer of cells growing up

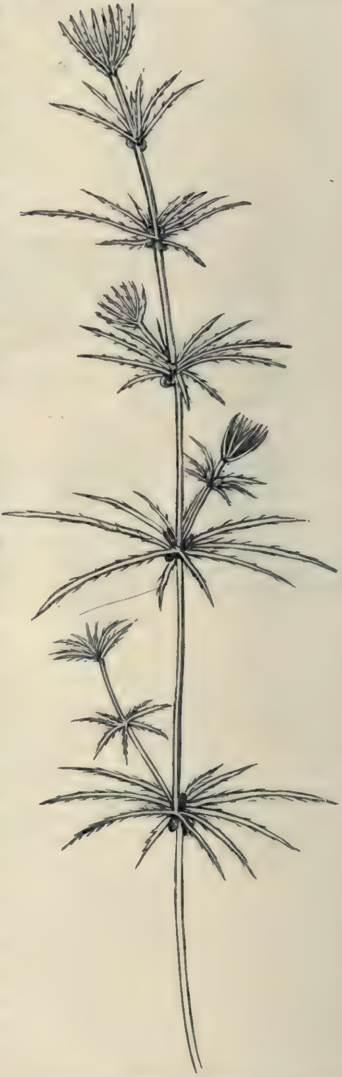


FIG. 496.—Portion of Chara plant, about natural size, showing arrangement of leaves and branches.

from the base and coiled spirally around it, and these are surmounted by a crown, which in Chara consists of five and in Nitella of ten smaller cells, which originate from the others by transverse division. Thus, just before maturity, the germ-cell is completely enclosed, but when ready for fertilization, an opening occurs between the cells at the apex, and this becomes filled with mucilage, and the wall of the germ-cell is also converted into mucilage at its apex, permitting the entrance of the antherozoids. The oögonium, when mature, is oblong or ellipsoidal in form and of a deep orange color. See Fig. 497.

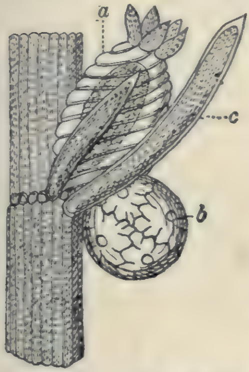


FIG. 497.—Small portion of Chara stem, showing one node on which are borne an oögonium, *a*, and an antheridium, *b*. *c* is a leaf, most of the other leaves having been removed. Enlarged about ten diameters.

The antheridium is a spherical body nearly as large as the oögonium, and also orange-colored when ripe. Its walls are composed of eight triangular cells, whose edges are serrated or wavy, and nicely dovetail into each other. To the centre of each one of these cells, and projecting interiorly, is attached a cylindrical cell, called the *manubrium*, and this bears at its inner apex a rounded cell called the *head-cell*. This, in turn, is surmounted by about six smaller cells, from which proceed a number of small, coiled filaments, each made up of about two hundred disc-shaped cells. In all, each antheridium contains from one hundred to two hundred of these filaments. See Fig. 498. When the antheridium is ripe the segments of the wall separate, and from each cell of the filaments there escapes a minute, slender, coiled antherozoid, pro-

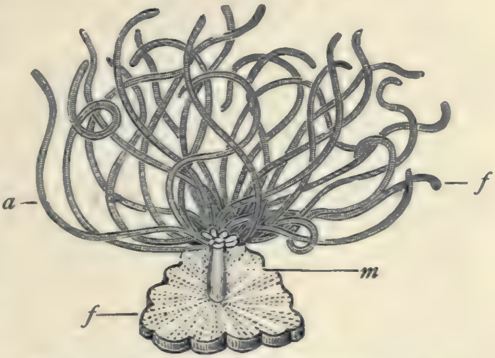


FIG. 498.—Segment of Antheridium of Chara. *a*, one of the wall-cells ; *m*, manubrium ; *f*, *f*, antheridial filaments. Magnified about 100 diameters.

vided at its smaller end with two long cilia, by means of which it moves actively through the water. Some of them find their way into the oögonia and fertilize them. See Fig. 499.

The ripe spore rests for a time, and then, either in the autumn or early spring, germinates. It does not, however, immediately produce the leafy plant, but develops a different one, called the pro-embryo. From this the leafy plant springs as a lateral shoot, and the pro-embryo afterward perishes.

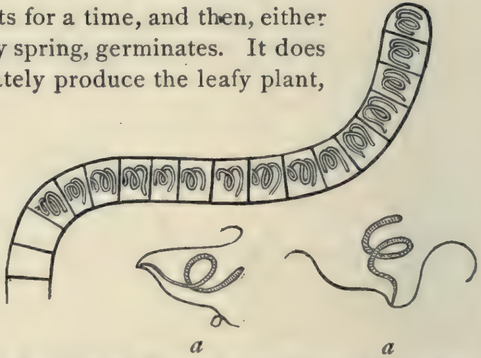


FIG. 499.—Portion of one of the antheridial filaments, magnified about 800 diameters, showing antherozoids in all of the cells but two; from these the antherozoids have escaped, and are shown at *a*, *a*.

CHAPTER VI.—THE THALLOPHYTA. ALGÆ (CONT'D).

THE MELANOPHYCEÆ—THE FLORIDEÆ.

THE MELANOPHYCEÆ or *Phæophyceæ*, as they are also called, are all marine plants, and are among the most abundant as well as the largest plants of the ocean. While some are of small size, others attain gigantic dimensions, Macrocystis, for instance, having a length of stem which considerably exceeds that of the tallest Australian Eucalyptus trees and California Conifers. In complexity of structure, also, the group presents great differences, some being quite simple, others among the most complex of their class, but the simplest are connected with the most complex by almost innumerable gradations.

They all possess, in addition to chlorophyll, a peculiar brown coloring matter related to that found in the Diatoms, and hence they have an olive-green or brownish instead of a bright-green color. They are, on this account, called Brown Sea-weeds.

Many of them produce swarm-spores, which are peculiar in the fact that the cilia are not located at the colorless apex, as in the Chlorophyceæ, but some distance back of it. In many of the lower forms the spores are asexual, in others some of them conjugate to produce zygospores, in still others distinct oöspheres and antherozoids are produced.

Between the last two are forms in which the sexual cells differ from each other but little except in size, so that in respect to reproduction, also, the group forms a closely related series.

All the forms which produce oöspheres have the peculiarity that the latter are ejected from the oögonia and become entirely free from the plant previous to the act of fertilization. Moreover, except in a few transitorial forms, the oöspheres are not endowed with the power of locomotion.

There are two principal divisions of the sub-class, the *Phæosporeæ*, and the *Fucaceæ*.

The term **Phæosporeæ** literally means dusky-spored, and is applied to the group because of the usually dark color of the sporangia. Many of the species have been observed to produce gemmæ, or to multiply by the separation of branches; but spore-reproduction, except in Cutleria and its allies, takes place by means of swarm-spores. In some species the swarm-spores have been observed to conjugate, but there is no observable difference between those which do and those which do not. Some species produce only round, dark-colored, unilocular sporangia; others produce these and also oblong multilocular sporangia. In Cutleria two kinds of spores, one larger and the other smaller, are produced in different kinds of multilocular sporangia; the former are to be regarded as oöspheres, the latter as antherozoids.

The most familiar members of the group are the Laminarias or Sea-aprons. These are plants of rather large size, often attaining a length of eight or ten feet. They have cylindrical stems of varying length, and often attaining the diameter of an inch or more. The base is attached firmly to rocks or other marine objects by means of strong, branching rhizoids, and the upper part expands into a flattened, leathery, blade-like organ, which in some species is entire; in others more or less divided. The blade and stem increase in length in a peculiar manner, namely, by the formation of new cells at the junction of the two organs, and the stem also increases in diameter by means of a growing layer beneath the rind, reminding us of the growth of the stems of Dicotyledons. The sporangia, which are of the unilocular variety, are borne on the lamina; and though probably the plants reproduce sexually, the fact of conjugation has not yet been observed.

Fig. 500 represents a plant of Laminaria saccharina, about one-thirtieth natural size. To this group also belong the Ectocarpeæ, the Sphacelarieæ, the Lessonias and the gigantic Macrocystis.

The Fucaceæ are dark olive-green algæ of considerable size, and having a cartilaginous consistency. Most of them adhere firmly to rocks by means of branching discs, but a few float free in the ocean waters. The vegetative body consists either of a dichotomously branching, more or less flattened thallus, as in the genus Fucus, or of fairly differentiated stems and leaves, as in Sargassum. Many of the species possess air-bladders, which render the branches buoyant.

They differ from the previous group, in not producing swarm-spores, as well as in their more complex mode of sexual reproduction. This takes place by means of antheridia and oögonia.

We may take the common Bladder-wrack, Fucus vesiculosus, as the type of the group. A portion of the plant is shown in Fig. 501. It grows attached to rocks between high and low tide. The frond is flattened, cartilaginous, two or three feet in length, and repeatedly forking. It has a prominent midrib, and on either side of it, at intervals, air-vesicles occur in pairs. The fruiting organs occur at the ends of certain branches, in cavities called conceptacles, which are arranged close together, and consist of

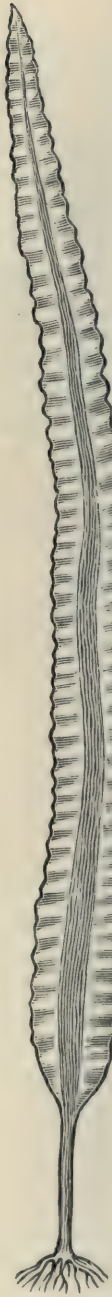


FIG. 500.

FIG. 500.—Laminaria saccharina, about one-thirtieth natural size.

globular depressions in the surface. The walls of the conceptacles are lined with hairs, some of which protrude from the narrow opening. Among these hairs, on the interior of some of the conceptacles, are borne antheridia, and in others oögonia; but in some species, for example, Fucus platycarpus, both are borne in the same conceptacle. A female conceptacle is shown in Fig. 502.

The antheridia are branching filaments, some of the cells of which, when mature, emit numerous bi-ciliated antherozoids. These find their way to the oöspheres, which, in the meantime, have escaped from the oögonia and fertilize them. Fig. 503 shows one of the branching filaments bearing antheridia.

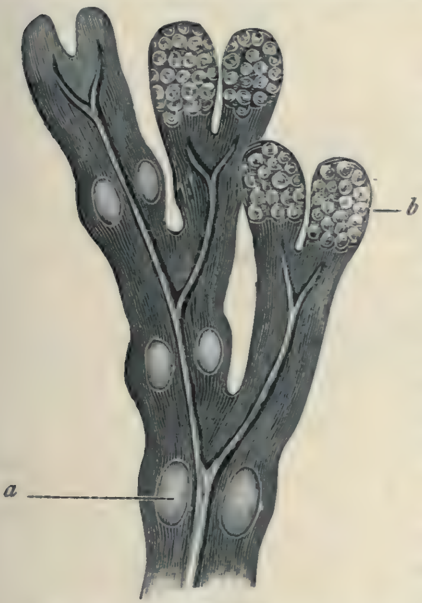


Fig. 501.—Portion of thallus of Fucus vesiculosus about natural size: *a*, one of the bladders; *b*, fruiting organs.

The oögonium begins as a minute papilla-like protuberance on the wall of the conceptacle, and is at first a single cell. This divides transversely into two cells, the lower one constituting the stalk, and the other becoming the oögonium proper. This becomes relatively large in size and spheroidal in form, and, in this species, the protoplasmic contents break up into eight nearly equal portions, forming as many oöspheres. In most other members of the order, either no division takes place, and but a single oösphere is formed within the oögonium, or else fewer are formed than in Fucus.

When the oöspheres are fully formed, the wall of the oögonium ruptures and they are discharged into the water, and there the antherozoids swarm about them and fertilize them. See Fig. 504. After this process is completed the oöspore acquires a cell wall, and soon begins to germinate.

THE FLORIDEÆ, OR RHODOPHYCEÆ.

This group includes the red or violet-colored algæ, popularly known as "Sea-Mosses," or Red Marine Algæ. They are exceedingly numerous in species, and are widely distributed in ocean waters. A few also, as Batrachospermum and Bangia, inhabit fresh-waters. The marine forms mostly grow attached to rocks or shells below the level of low tide. They are chlorophyll-plants, but the proper green color is more or less obscured by the presence of a red or violet coloring matter. In the simpler forms the thallus consists of branching filaments; in others it

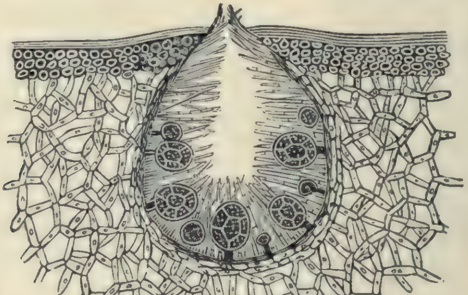


FIG. 502.

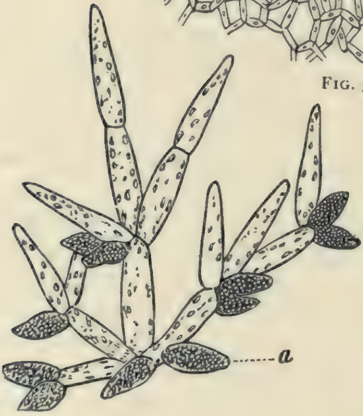


FIG. 503.

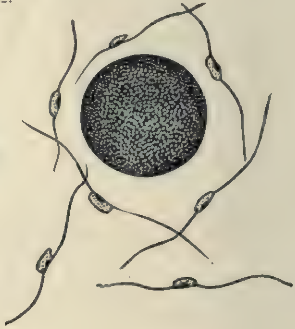


FIG. 504.

FIG. 502.—Female conceptacle of Fucus versiculosus, producing on its interior hairs and oögonia. Magnified about 40 diameters.

FIG. 503.—One of the branching filaments from a male conceptacle, bearing antheridia, *a*. Magnified about 150 diameters.

FIG. 504.—Escaped oösphere from one of the oögonia, with ciliated antherozoids swarming about it. Magnified about 400 diameters.

forms a flat expansion, consisting of one or more strata of cells, sometimes with a midrib, giving the structure an appearance something like that of a leaf; in other instances tissue-like structures, often possessing considerable complexity, originate from the growing together of adjacent branches; and in still others true tissues appear to be formed. In the majority of cases growth takes place by the division of a single apical cell, but in the Corallines and their relatives, there are usually several initial cells. This group is also distinguished from the rest by the fact that they secrete large quantities of lime in their cells.

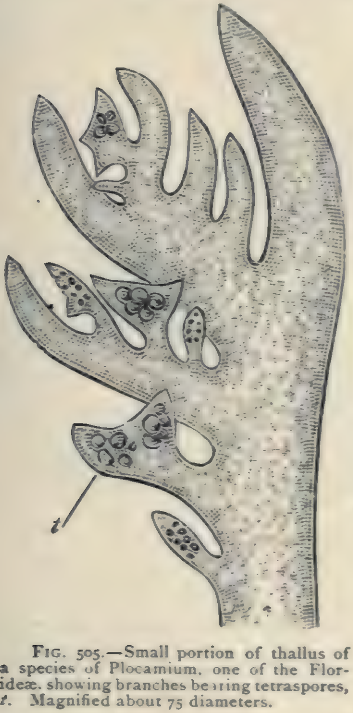


FIG. 505.—Small portion of thallus of a species of Plocamium, one of the Florideæ, showing branches bearing tetraspores, *t*. Magnified about 75 diameters.

The most distinguishing characteristic of the Florideæ is their mode of reproduction. In their asexual reproduction they produce non-motile cells, called *tetraspores*, which, as the name indicates, are usually formed in fours in the mother-cell. This, however, is not always the case; sometimes there are but one or two, occasionally as many as eight. In the forms which consist of branching filaments, the tetraspores are usually formed in the terminal cells of the branches; in other species they are usually imbedded in clusters in the tissues of certain branches, which consequently often acquire a form quite different from the rest. Plants which reproduce asexually by tetraspores, do not usually possess the organs of sexual reproduction, though there are some exceptions to the rule. Fig. 505 represents a small portion of the thallus of a species of Plocamium highly magnified, showing tetraspores.

The sexual organs consist of antheridia and carpogonia. These may both be borne on the same plant, or, as is more commonly the case, on separate plants of the same species. The antheridia occur either singly or in groups at the ends of certain branches, and the antherozoids are minute rounded, non-ciliated and non-motile particles, and are dependent therefore on water-currents or on animalculæ for their conveyance to the carpogonia. The latter are more complex organs than the oögonia of other algæ. In the course of their development, the unicellular or multicellular mass first formed becomes differentiated into two portions, an upper portion, called the *trichogyne*, usually a straight, hair-like process, and an enlarged basal portion.

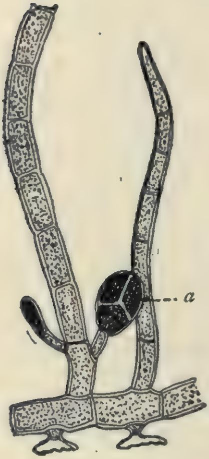


FIG. 506.

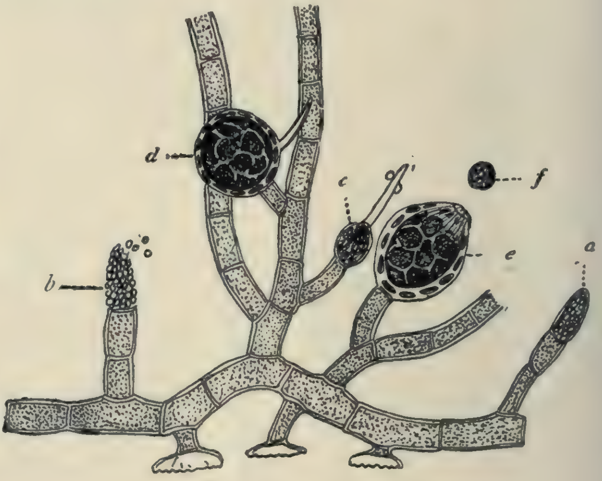


FIG. 507.

FIG. 506.—Lejolisia mediterranea, one of the Red Marine Algæ ; portion of filament, showing asexual reproduction by tetraspores. *a*, represents tetrasporangium. Three of the four spores are shown in the figure, the other is concealed behind them.

FIG. 507.—Lejolisia mediterranea ; portion of fertile filament, showing mode of sexual reproduction. *a*, antheridium nearly ripe ; *b*, ripe antheridium with escaping antherozoids ; *c*, carpogonium, bearing at its apex a trichogyne, to which two antherozoids are attached ; *d*, nearly ripe carpogonium, showing carpospores in its interior ; *e*, ripe carpogonium discharging one of its carpospores, *f*. Magnified about 150 diameters.

The part which receives the fertilizing influence of the antherozoids is the trichogyne, but this does not undergo development in consequence, but communicates the influence to the basal portion, and then soon withers away, while the latter undergoes very considerable changes. These differ considerably in different species, but in all, the fertilization stimulates a considerable vegetative growth, which results in the production of spores, sometimes quite a large number of them in one carpogonium. The spores thus produced are called *carpospores*.

In some cases, as in Nemalion, fertilization results in the out-growth of several branches from the basal part, which break up into cells, each one of which becomes a carpospore. In other cases, as in Lejolisia, the stimulant influence results in the development of adjacent cells to form filaments which grow up around the fertilized cell, and unite laterally to form an envelope to enclose the spores, which, in the meantime, are formed by the division of the fertilized cell. Both the sexual and asexual processes in this plant are illustrated in Figs. 506 and 507.

CHAPTER VII.—THE THALLOPHYTA (CONTINUED).

CLASS IV.—THE FUNGI.

THE CHYTRIDIEÆ—THE USTILAGNIEÆ—THE PHYCOMYCETES—THE ASCOMYCETES.

The Fungi are, in their habits, chlorophylless saprophytes or parasites. In all but a few instances their vegetative parts consist of slender segmented or unsegmented usually colorless filaments, called hyphæ, which ramify among decaying organic debris, or invade the tissues of living organisms, plant or animal, and derive their nourishment from them. The only members which do not produce hyphæ are some of the lowest Fungi belonging to the Chytridieæ and certain degenerate higher forms, such as the Yeast-plant. Here the whole vegetative portion of the plant consists of rounded cells or chains of cells. In the higher Chytridieæ, however, some of the cells emit slender branches, which may be regarded as rudimentary hyphæ.

In the simpler hyphal forms, the hyphæ occur singly or more or less interwoven into a tangled felt-work, but they are not gathered into definite forms, and have little or no dependence upon each other; in the higher groups, however, there is more or less division of labor among the hyphæ, and they become consolidated into false tissues, which acquire definite shapes according to the species. Of this character are the fructifying organs or *carpophores*, which constitute the above-ground parts of the Agarics, Puff-balls, Cup-fungi, etc., and the *sclerotium*, a compact, hard mass of thick-walled hyphæ, which serves as a resting-stage in the development of some species, as the Ergot of Rye and some others.

The Fungi reproduce asexually by means of *conidia* or *gonidia*, as they are also called. In some species, chiefly aquatic forms, these are motile spores provided with cilia, but in most, they are non-motile thick-walled cells, which become separated from the parent hyphæ in ways which are more or less characteristic in the different groups.

In all hyphal Fungi, the hyphæ consist of two portions, the vegetative, which ramify in the substratum, often forming tangled felt-like masses of threads, called the *mycelium*, and the reproductive, which come to the surface; it is the latter which produce the conidia. They may be borne on isolated filaments, as in the Bread-mould (Penicillium), or on a carpophore, which produces a spore-bearing *hymenium*. The common Mushroom (Agaricus campestris), is an example of the latter, the plate-like bodies or gills, on the under surface of the cap, constituting the hymenium.

In a large number of Fungi, including some of the most highly organized forms, sexual reproduction is unknown. Doubtless in many it yet remains to be discovered, but there is good reason to believe that in some the power once possessed has been lost. This is believed to be true of the Basidiomycetes—the group to which belong the Agarics, Polypori, Puff-balls, etc.

In other species, however, for example, Mucor, sexual reproduction takes place, as in Mesocarpus, by conjugation; in still others, as in Achlya and Peronospora, it takes place by the production of oöspores in a manner similar to that in the oösporous Algæ. In fact, we may regard these Fungi as degenerate parasitic or saprophytic forms of Algæ analogous to the saprophytic Ericaceæ, and other chlorophylless flowering-plants.

In other forms, as, for example, the Cup-fungi, an act of fertilization precedes the development of the hymenium-bearing carpophore, and is the stimulant cause of it.

The more recent classification of Fungi distributes them into six orders, as follows: The *Chytridieæ*, the *Ustilagineæ*, the *Phycomycetes*, the *Ascomycetes*, the *Æcidiomycetes or Urednieæ*, and the *Basidiomycetes.*

THE CHYTRIDIEÆ.

This order, as we have seen, are Fungi of the simplest organization, most of them being unicellular, and not producing hyphæ, while a few of the higher forms produce rudimentary hyphæ. They reproduce asexually by means of uniciliated swarm-spores. Sexual reproduction has been observed in but one species, and in this instance it takes place by conjugation. In the typical genus Chytridium, the plants are unicellular, and their habitat is the interior of the living or dead tissues of aquatic Fungi and Algæ. The cells, on reaching maturity, become sporangia and emit swarm-spores, which again germinate in the same plant, or, escaping, find their way to others and there germinate. See Fig. 508.

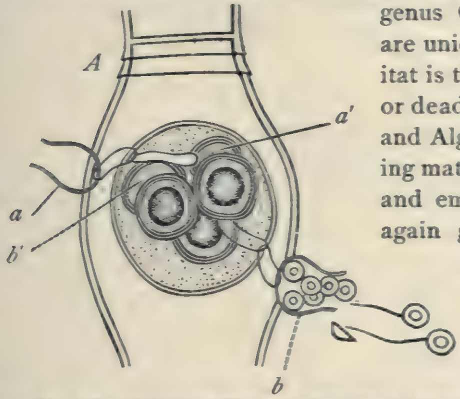


FIG. 508.—Chytridium Olla. *A*, oögonium of Œdogonium rivulare, with an immature oöspore killed by the parasite; the oöspore contains several resting-spores of Chytridium, which ripened in October; three of these spores are still unchanged; two have germinated. By turning the specimen round, it was seen distinctly that the empty sporangium *a*, was formed from the resting-spore *a'*, and the sporangium *b*, which is ejecting its contents, from *b'*; near the mouth of *b*, are the cast-off lid and two zoöspores. Magnified 600 diameters. Figure and description after De Bary.

THE USTILAGINEÆ.

The Ustilagineæ or Smut-Fungi, of which the common Corn-smut, Ustilago Maidis, may be taken as the type, are parasitic upon flowering-plants. The slender mycelial threads usually penetrate through the intercellular spaces of the host-plant, and in some species send sucker-like branches, called *haustoria*, into its cells. In some instances the parasite attacks the seedling plant and sends its hyphæ through the whole structure, growing as it grows; in others it attacks the more mature plant, and confines its ravages to certain parts.

At maturity it produces, either at the outside of the host-plant, or in its inter-cellular spaces, very numerous spores on tangled mycelial filaments. These most frequently occur on the inflorescence, or on parts adjacent to it, and the spore-masses, together with the abnormal growth caused by it, often assume quite characteristic forms. Corn-smut forms irregular, roundish-lobed masses, often attaining a diameter of six inches or more. The masses consist of a translucent gelatinous membrane enclosing innumerable blackish-brown, rounded spores, having a nodular surface. The spores, in many species at least, do not, when germinating, at once produce the slender mycelial threads already described, but give rise to a pro-mycelium from which cells are separated, which develop into a true mycelium. In some instances, however, these secondary spores have been observed to conjugate.

THE PHYCOMYCETES.

The term Phycomycetes literally means "Sea-weed Fungi," and alludes to the resemblance, in the mode of sexual reproduction, between these plants and certain of the Algæ. They produce a copious mycelium, which usually consists of unsegmented hyphæ, bear conidia, and most of them reproduce sexually either by zygospores or oöspores.

There are three sub-orders, the *Zygomycetes*, the *Peronosporeæ*, and the *Saprolegnieæ*.

Of the **Zygomycetes**, or Conjugating-Fungi, Mucor Mucedo may be taken as an example. This mould is a very common one found growing on various kinds of decaying matters, such as horse-dung, rotten fruits, etc. The hyphæ branch profusely through the substratum, whatever it may be, deriving nourishment from it. The fruiting hyphæ, however, are simple, and grow out into the air, each bearing at its tip a globular, blackish sporangium, the wall of which soon ruptures, setting free numerous conidia. This is the asexual mode of reproduction. Sexual reproduction takes place by the conjugation of some of the interior hyphæ. The large, rounded, nodular zygospores are formed between the filaments. These rest for a time before germinating, and then, if the supply of nourishment is sufficient, develop a copious vegetative mycelium; if insufficiently nourished they produce at once aerial hyphæ, bearing sporangia. The modes of reproduction in this plant are illustrated in Fig. 509.

The *Entomophthoreæ*, which are parasitic upon insects of various kinds, are also probably to be classed here. Of these Empusa Muscæ, which infests house-flies, and Entomophthora radicans, which often destroys the larvæ of the Cabbage-butterfly, are common examples. Some of the species have been observed to form zygospores.

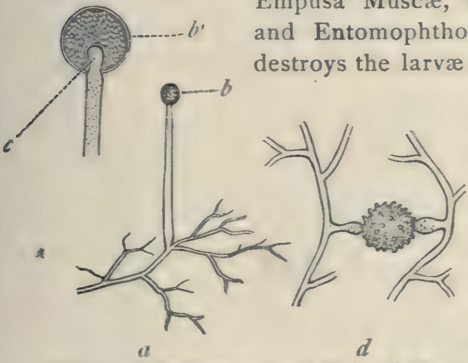


FIG. 509.—Mucor mucedo. *a*, a portion of vegetative mycelium, bearing an aerial hypha, terminated by a sporangium, *b*; *b'*, sporangium more highly magnified, showing the contained conidia; *c*, columella; *d*, conjugating mycelial filaments, with a zygospore formed between.

The Peronosporeæ are mainly parasitic on terrestrial Phanerogams; a few, however, as some of the species of Pythium, are saprophytic, feeding upon dead animal and vegetable matters. They produce unsegmented hyphæ which ramify in the intercellular spaces of their hosts and, sending haustoria into adjacent cells, absorb nourishment from them. The great majority, after a time, send hyphæ to the surface, frequently out through the stomata of the plant, and these bear sporangia which are shed, when ripe, in the same manner as conidia, and hence are commonly so called, though they differ from them in the fact that when they fall into water, the contents break up into several rounded masses which escape as zoöspores. These, after finding a lodgment on the epidermis of the host-plant, come to rest and produce hyphæ, which either penetrate the walls of the epidermal cells or find their way into the interior through the stomata. A few of the forms, however, produce true conidia which give rise to hyphæ directly; a few others neither produce conidia nor sporangia.

Nearly all the species reproduce sexually by means of oögonia and antheridia. The oögonium formed at the end of a hyphal branch is similar in structure to the corresponding organ in the oösporous Algæ, but the antheridia consist of one or more slender, curved out-growths, from the branch beneath the oögonium, or sometimes from adjacent hyphæ. In fertilization the antheridium applies itself directly to the surface of the oögonium, and usually a tube from it penetrates to the oösphere and fertilizes it. In most cases the oöspores rest for a considerable period before germinating, and then, in some cases, develop a mycelium directly, in others they first produce a germ-tube which develops one or more sporangia which give rise to zoöspores, and these, in turn, to a vegetative mycelium.

To the Peronosporeæ belong Phytophthora infestans, a mould which produces potato disease ; Peronospora viticola, the Grape-mildew, a most destructive Fungus, and Cystopus candidus, a mildew found on the Shepherd's-purse and some other Cruciferous plants.

Some idea of the modes of reproduction in this group may be obtained from Figs. 510 and 511.

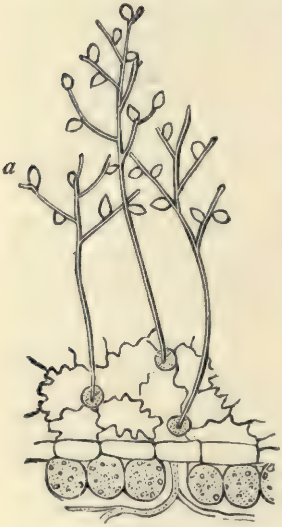


Fig. 510.

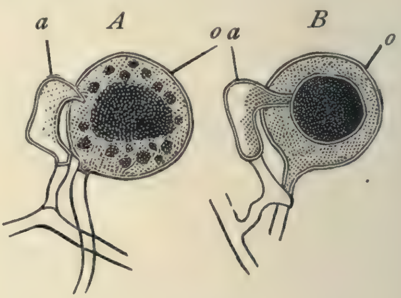


Fig. 511.

Fig. 510.—Portion of epidermis of Potato, showing three stomata with hyphæ of Phytophthora infestans issuing from them and bearing sporangia. *a*, one of the sporangia. Magnification about 100 diameters.

Fig. 511.—Stages in reproduction of Peronospora Alsinearum. *A*, earlier stage, fertilization-tube of antheridium, *a*, not yet fully formed; *B*, the tube fully formed and the fertilization of the oogonium, *o*, completed. Magnified about 350 diameters. After DeBary.

The **Saprolegnieæ** are aquatic plants which form a dense mycelium on the bodies of animals that decay in water, and sometimes also upon submerged vegetable matter. They resemble the Peronosporeæ in many respects, but differ from them in the fact that the sporangia produce ciliated swarm-spores, and in the fact that the fertilized oögonia produce several oöspores instead of one.

A curious and suggestive fact connected with some of the species of this group is, that while oögonia and oöspores are produced as in the rest, either antheridia are not produced at all, or these do not perform the usual function of fertilization. The sexual process has in fact degenerated into an asexual one. This phenomenon is particularly observed in the genus Saprolegnia, and, as we shall presently see, is a common one among the higher groups of the Fungi.

Achlya lignicola, which feeds upon decaying, submerged wood, illustrates well the perfect forms of the group. See Fig. 512 A and B.

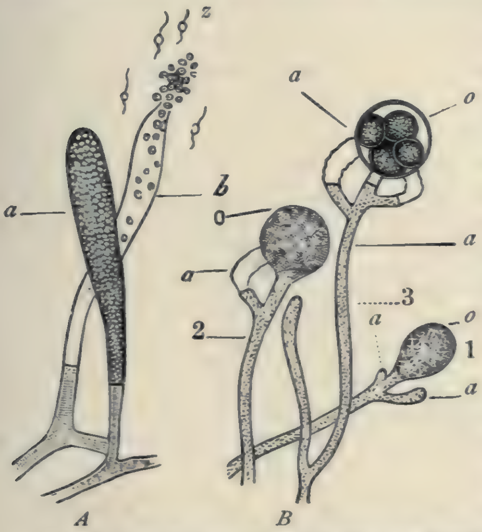


FIG. 512.—Achlya lignicola. *A*, Sporangia; *a*, sporangium nearly ripe but not yet dehiscent; *b*, sporangium dehiscing; *z*, zoöspores. *B*, Stages in sexual reproduction. In 1, the oögonium, *o*, and the antheridia, *a*, *a*, not yet fully formed; 2, later stages when oögonium is nearly ready for fertilization; 3, process completed and antheridia withering away. Magnified about 300 diameters.

CHAPTER VIII.—THE THALLOPHYTA.

THE FUNGI (CONTINUED).

THE ASCOMYCETES.

This order consists, for the most part, of saprophytic hyphal fungi, which produce a multicellular mycelium and on the whole attain a complexity of structure exceeding that of any of the groups already described. A few, however, as the Yeast-plant and its allies, are among the simplest of vegetable organisms. Many of them reproduce by means of conidia, and these may be formed from hyphæ by the separation of cells in succession from their free ends—a process called *abjunction*—or they may be produced in special receptacles. But their most distinctive characteristic is the production of *ascospores*. These are spores formed by internal cell-formation, in certain large cells usually the terminal ones of hyphæ. The spores are usually eight in number, but in some species there are but two and, in others four or five. They have a thick outer wall and a thin extensible inner one. When placed under conditions favorable for germination, the outer wall bursts and the inner extends to form one or more tubes, from which the hyphæ develop.

Usually the asci are produced in a specially developed organ or sporocarp, which is often a complex structure constituting the most conspicuous part of the plant; but in a few forms the asci are isolated, and not borne in a special fruiting-organ; and in other cases the latter is present, but has the simplest possible structure. Normally, the production of a sporocarp and ascospores, is the result of an antecedent sexual process analogous to that which occurs in most Phycomycetes, but this is not always the case; in a large number of instances the organs of sexual reproduction either exist only in a rudimentary condition, or have entirely disappeared.

When sexual reproduction occurs, it takes place by means of an *archicarp* and an antheridium, the former corresponding to the oögonium of the Peronosporeæ, but differing from it in the fact that no oöspores are developed within it, as well as in the fact that the collateral growths resulting from fertilization are usually very different.

In some of the simpler species, the end of a hyphal branch becomes enlarged and ellipsoidal in form, and is separated from the rest by a septum to form the archicarp, and an adjacent branch becomes less thickened, has its apical portion separated from the rest by a septum in a similar manner, and becomes an antheridium. In most cases, however, the filament that forms the archicarp becomes twisted into a spiral, and covered perhaps by an out-growth of adjacent hyphæ to form a compact mass. This may be provided with a projecting filament, or trichogyne, which receives the fertilizing influence, or it may be without it.

In the species which do not produce a trichogyne, the antheridium becomes entangled with the coiled filaments of the archicarp, and thus fertilizes them; in the species that do produce one, the antheridium, when ripe, discharges *spermatia,* small fertilizing cells without cilia, which, by adhering to the trichogyne, fertilize the archicarp.

The principal divisions of the Ascomycetes are the *Erysipheæ*, the *Tuberaceæ*, the *Pyrenomycetes*, and the *Discomycetes*. But here are also classed *Gymnoascus*, a small fungus often found on the dung of horses and other domestic animals, and which produces a very simple fructification, consisting of short, branched filaments, bearing several unenclosed asci. Here also are placed, provisionally at least, the *Saccharomycetes* or Yeast-fungi, and the apparently related *Exoascus*, one species of which produces the disease called "bladder-plum," in the fruits of various species of Prunus.

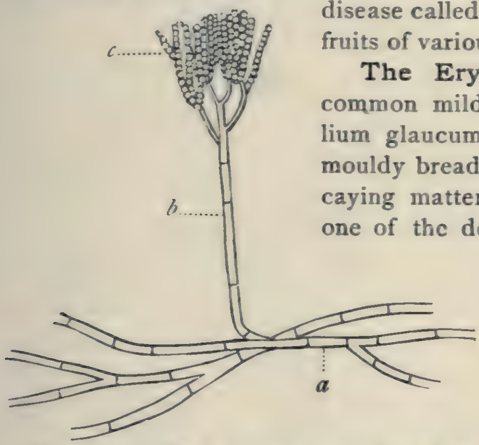


FIG. 513.—Penicillium glaucum. *a*, mycelium; *b*, conidia-bearing hypha; *c*, conidia. Magnified about 150 diameters.

The Erysipheæ include the common mildew or blight, Penicillium glaucum, found frequently on mouldy bread, and various other decaying matters; Erysiphe Tuckeri, one of the destructive blights that infest the grape; and Eurotium repens and Eurotium Aspergillus-glaucus, the mildews most common on preserved fruits. In these the fructifications are small and usually rounded, consisting of a few asci enclosed in a false parenchyma tissue. Some of them, however, for example, Penicillium glaucum, only exceptionally produce an ascosporous fructification, reproduction ordinarily taking place by means of conidia. See Fig. 513.

The sexual and asexual modes of reproduction in Eurotium repens are illustrated in Fig. 514.

The Tuberaceæ are, many of them, highly prized for food, under the name of Truffles. They produce subterranean, tuber-like fructifications from a mycelium that penetrates through the soil, and, in some instances at least, is parasitic on the roots of trees. The fructification is usually spheroidal, and invested with a tough cortical layer. The ascospores are produced in intricately winding passages in the interior. Each ascus contains from two to four spores, which are set free by the decay of the surrounding parts. Sexual organs are not known in these Fungi, nor has the mode of germination of the spores been observed. The most prized of the edible species are Tuber æstivum and Tuber melanosporum.

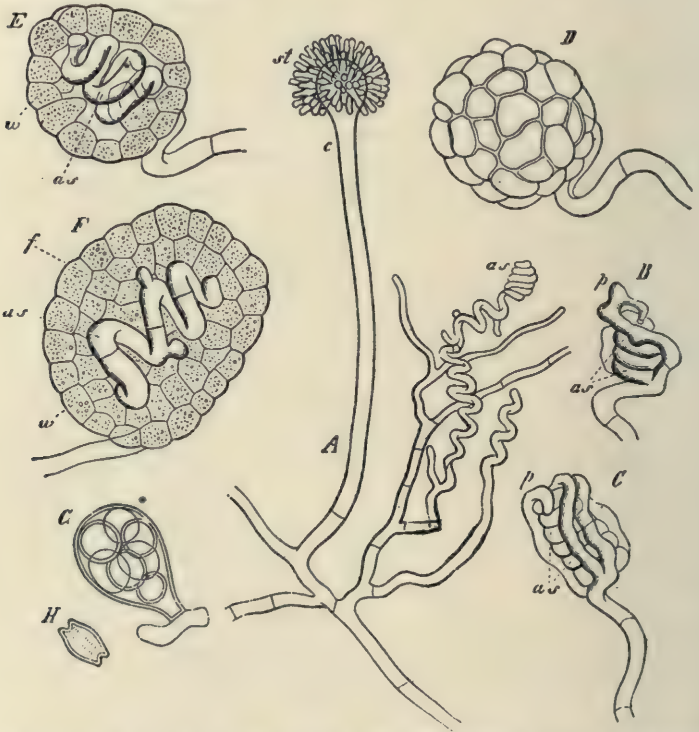


Fig. 514.—Eurotium repens. *A*, branch of mycelium bearing conidia, *c*, and young archicarps, *as*; *B*, spirally twisted archicarp *as*, with the antheridial branch *p*, and an envelope branch; *C*, older specimen with more envelope branches, and *p*, antheridial branch; *D*, young sporocarp seen from without. *E* and *F*, other sporocarps in longitudinal section; *G*, ascus with spores. *A*, magnified 190 diameters, the rest about 600 diameters. After De Bary.

The Pryrenomycetes are characterized by producing long club-shaped asci in the interior of a roundish or flask-shaped receptacle or *perithecium*. The latter may occur singly, or many may be aggregated together on a common organ called a *stroma*. The group includes a number of genera, among them Diatrype, whose fructification forms black, warty-looking prominences about a fourth of an inch in diameter on dead boughs; Sphæria, which forms small black spots on decaying leaves; Cordiceps, whose various species are parasitic upon the bodies of insect larvæ; and Claviceps, whose species produce ergot on various kinds of grasses. Claviceps purpurea, which constitutes, in one stage of its development, Ergot of Rye, may be selected for more particular description. This fungus begins its development on the Rye when it is in flower, and appears as a tangled mass of delicate threads on the surface of the ovary, also penetrating its tissues.

These mycelial threads produce numerous conidia imbedded in a yellowish mucus. This is called the *sphacelial* stage of the development of the Fungus. There then begins to form at the base of the diseased ovary, a dense mass of mycelium, which continues to enlarge until it forms the dense, hard, dark-purple sclerotium, called the Ergot-grain. This is termed the sclerotium stage of development.

The remains of the upper part of the ovary and the style are often seen attached to the apex of the Ergot-grain, even when the latter is mature, but it very soon afterwards falls off. Sometimes as many as twenty Ergot-grains are produced in a single diseased head of Rye, but more commonly not more than two or three. Each grain or sclerotium consists wholly of a hard and compact mass of mycelium, and contains no part of the original grain of Rye which it has displaced. This sclerotium lies dormant until spring, when, if placed in warm, damp soil, there arise from its interior a number of stalked bodies with globular heads. These are the stromata, and each contains just beneath its convex surface numerous flask-shaped perithecia, each of which contains many asci, and each ascus contains several delicate thread-like spores.

At maturity the asci rupture and discharge the spores, which, if they find their way to the young flowers of Rye, germinate and produce the mycelium, with which this description started, and so the cycle is completed. The successive steps in the reproduction of this Fungus are illustrated in Figs. 515 to 520 inclusive.

The Discomycetes differ from the rest of the group chiefly in the structure of the hymenium, which is on the surface of a

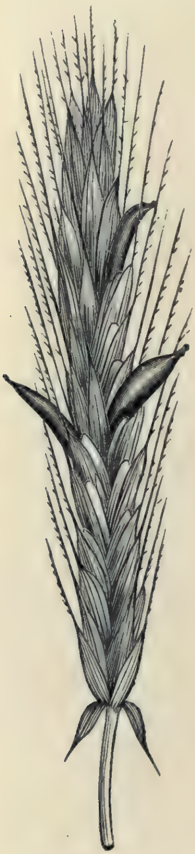


FIG. 515.

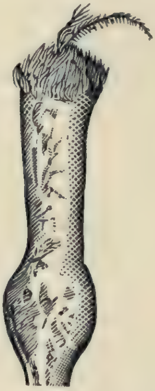


FIG. 516.

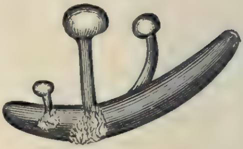


FIG. 517.

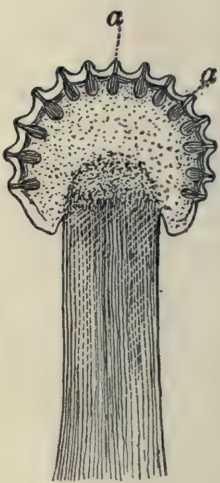


FIG. 518.

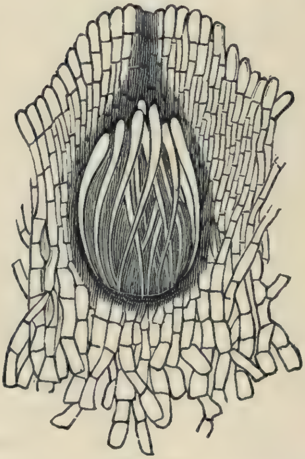


FIG. 519.

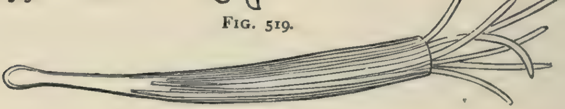


FIG. 520.

FIG. 515.—Head of Rye, bearing three Ergot-grains.

FIG. 516.—Pistil of Rye attacked by Ergot blight—Claviceps purpurea in the first or sphacelial stage of development. Somewhat magnified.

FIG. 517.—Ergot-grain after lying over winter, producing fructifying organs. Nearly natural size.

FIG. 518.—A fructifying organ or stroma of Ergot in longitudinal section, magnified. *a, a,* perithecia imbedded in the margin.

FIG. 519.—A perithecium much more highly magnified, showing the club-shaped asci in its interior.

FIG. 520.—One of the asci greatly magnified, shown in the act of discharging its ascospores. The discharge really takes place from the ascus, before it leaves the perithecium.

discoid, cup-shaped or club-shaped fructification, which may or may not be the result of an antecedent fertilizing process which takes place in the mycelium growing in the substratum. Some of the forms are parasitic, others saprophytic. The group includes the largest and most highly developed members of the Ascomycetes. Here belong the *Pezizas* or Cup-fungi, common in woods, growing upon leaf-mould and producing a cup-shaped sporocarp; the *Helvellas*, including Morchella (see Fig. 528), Helvella, etc., which have large, mostly club-shaped, sporocarps, the hymenium of which is borne either on a smooth or on a reticulately indented surface; and the Phacideæ, which produce small, blackish, disc-like or roundish fructifications on dead leaves of various kinds.

The fungus parts of most Lichens also belong in this group, but owing to the composite character of these plants they had best be considered separately.

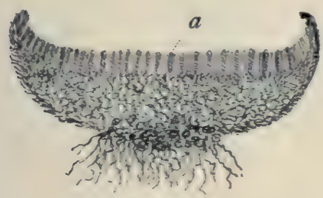


FIG. 521.

FIG. 521.—Diagram of longitudinal section of sporocarp of Peziza. *a*, hymenium.

FIG. 522.—Some of the asci in various stages of development, the more mature showing eight oblong ascospores. The slender filaments between the asci are called paraphyses.

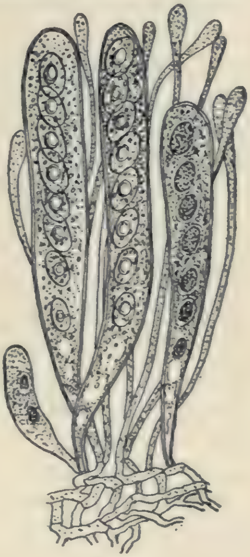


FIG. 522.

For a fuller illustration of the life history of these plants we may take Peziza confluens. The mycelium grows in soil rich in organic remains, and sends up ascending branches which develop numerous archicarps arranged in rosettes. Each archicarp is ellipsoidal in shape and tipped with a slender, usually curved, process. Into contact with this grows the antheridium, a slender or somewhat club-shaped branch which sprouts from beneath the archicarp. After the fertilization is effected, numerous hyphæ are developed around the rosette of archicarps until a mass of considerable size is formed; on the upper surface is developed a hymenial layer of closely compacted erect hyphal branches; the whole sporocarp gradually assumes the form of a cup, and many of the hyphal branches in the hymenium develop into eight-spored asci. Fig. 521 is a diagram of one of the sporocarps, and Fig. 522 illustrates some of the asci in various stages of development.

The *Saccharomycetes*, as has already been stated, are now classed among the Ascomycetes and are regarded as degenerate members of the group. They include most of the forms which are capable of exciting the alcoholic fermentation in saccharine liquids. They are minute plants of very simple structure, consisting of rounded or ellipsoidal cells, which either occur singly or loosely united into short chains. The cells are non-nucleated, or, at any rate, no nucleus has yet been observed in them; they contain a vacuole, and, when growing in a suitable medium, they increase rapidly by budding or sprouting. This is their principal and, under ordinary circumstances, their only mode of increase, but when deprived of sufficient nourishment, as for example when wine-ferment is cultivated for several days on a porous tile kept moist under a bell-jar, the cells cease sprouting and the contents break up into ascospores, from two to four of these being produced in each cell.

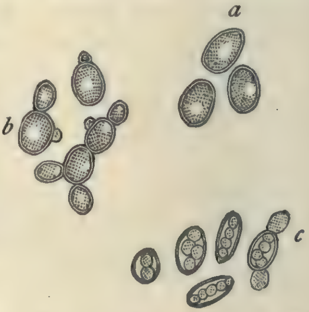


FIG. 523.—Yeast cells. *a*, cells of Saccharomyces Cerevisiæ, not sprouting; *b*, sprouting cells of the same plant; *c*, cells of S. ellipsoideus developing ascospores. All magnified about 700 diameters.

When growing in saccharine solutions they decompose the sugar mainly into alcohol, which remains in solution, and carbon dioxide, which escapes as gas. They have the peculiarity of being able to do without free oxygen, providing sugar is present in solution.

The best known members of the group are Saccharomyces Cerevisiæ, or brewer's yeast; S. ellipsoideus, or wine-ferment; S. albicans, the ferment which produces thrush, but which, under certain conditions, is also capable of exciting the alcoholic fermentation ; and S. Mycoderma, the so-called Flowers of wine. Cells of common yeast and wine-ferment are shown in Fig. 523.

CHAPTER IX.—The Thallophyta.

THE FUNGI (Continued).

The Æcidiomycetes—The Basidiomycetes.

The Æcidiomycetes, also called the Uredineæ, are popularly known as Rusts, and are parasites, forming yellowish, brownish or blackish spots on the stems and leaves of various plants. Some of them, as the Wheat-rust, are highly destructive to crops. The name *Æcidiomycetes*, refers to a peculiar form of fructification called "æcidium-fruits," which are produced by the species. These fruits consist of a cup-shaped envelope or peridium, in the bottom of which rows of cells are formed and separated one after the other, by transverse division, forming rounded spores called *æcidiospores.* They are only a peculiar form of conidia, and the whole fructifying organ corresponds, doubtless, to the sporocarp of the Ascomycetes. No sexual reproduction has actually been observed in any of the species, yet there is reason to believe it takes place ; for in some, minute spermatia are formed before the æcidium-fruits develop, and it is probably due to their fertilizing influence that the latter are produced.

In some species, the æcidiospores, on germinating, produce short, few-celled filaments, constituting a promycelium which soon ceases its vegetative growth and bears small conidia, called *sporids* or *sporidia.* These, when deposited by the wind or some other agency on a suitable host-plant, germinate and produce tubes which penetrate the epidermis or enter the stomata and develop a mycelium in the interior of the host-plant, and this mycelium again produces æcidium fruits.

In some of the species, however, the life-history is more complex, there being two distinct stages in it that are spent on different host-plants, and in which different sets of reproductive spores are developed. Of this group, the common wheat-rust, Puccinia graminis, may be taken as an illustration. This first makes its appearance in the form of yellowish or rust-colored patches on the stems and leaves of Wheat and other grasses. These spots are due to multitudes of yellowish spores, called *uredospores*, produced from a mycelium growing within the plant. These spores are dispersed by the wind, and if the season is damp and warm the infection rapidly spreads from plant to plant.

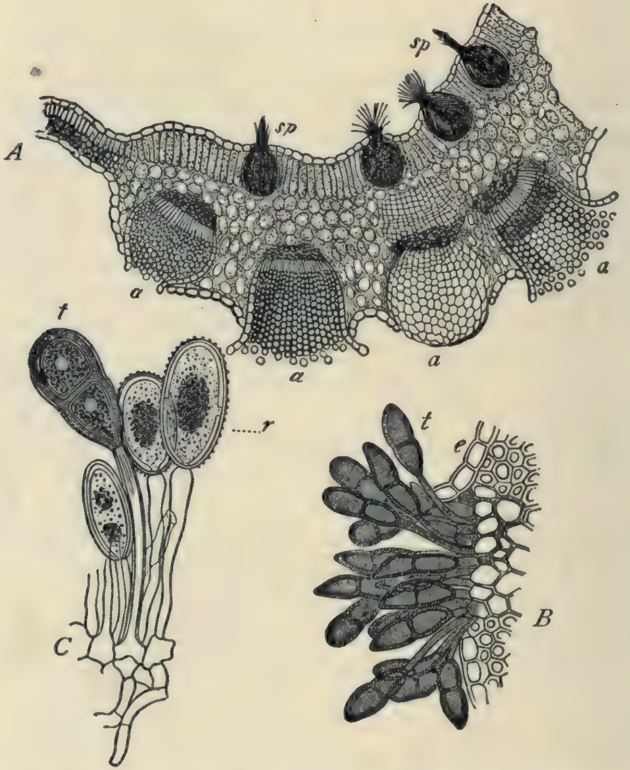


Fig. 524.—Puccinia graminis. *A*, part of thin cross-section of Barberry leaf showing four æcidium-fruits, *a*, *a*, *a*, *a*, in various stages of development on the under surface, and four spermogonia, *sp*, imbedded in the upper surface. *B*, group of ripe teleutospores bursting through the epidermis, *e*, of a leaf of Triticum repens. *C*, Uredospores, *r*, and teleutospore, *t*, more highly magnified. *A*, slightly magnified; *B*, magnified about 190 diameters, and *C*, magnified about 390 diameters. After Sachs.

Spore production of this kind continues until toward the close of the growing season, when the rust-like patches change to a darker, almost blackish color. This is due to the development of another kind of spores called *teleutospores*. These differ from the others in being two-celled and having thicker walls. Moreover, they are not capable of developing on a healthy blade of grass, but rest over winter in the straw, and in the spring germinate, producing a promycelium the branches of which bear sporidia. These are wafted away by the winds and germinate on the leaves of the Barberry and, perhaps, on other plants, but not on the Wheat. These immediately produce hyphæ which, penetrating the stomata, form a mycelium which derives nourishment from the cells of the leaf, and finally bursts through the epidermis and forms the æcidium fruits popularly known as "cluster-cups."

In these little cups are formed multitudes of small, rounded, yellow or orange-colored spores which the wind scatters. These do not germinate on the Barberry, but those which are conveyed to the leaves of grasses develop hyphæ, which penetrate to the interior of the leaf, and after a time produce the rust-like patches at the surface.

Some of the steps in the reproduction of this plant are shown in Figs. 524, A, B and C.

The phenomenon of alternation of generations, so prominent in this group, also occurs in some others and is likewise exemplified in some of the lower forms of animal life.

Other familiar plants belonging to the Æcidiomycetes are Uromyces Betæ, the rust of Beet-root; U. Pisi, a rust which preys upon many Papilionaceous plants; Chrysomyxa Abietis, a species parasitic on the leaves of Spruces and which produces golden-yellow teleutospores, and Puccinia straminis, which forms its æcidium-fruits on the leaves of the Borrages.

THE BASIDIOMYCETES.

The distinctive characteristic of this group is the fact that at the ends of the spore-bearing hyphæ, large, club-shaped or oblong cells are produced which bear at their apex delicate processes called *sterigmata*, two, eight or, more commonly, four in number, each of which is terminated by a rounded or ellipsoidal spore. The cells which bear the sterigmata are called *basidia*, and the spores, basidiospores. The basidia occur in large numbers compactly arranged, sometimes with intervening sterile filaments called paraphyses, on or in a definite part of the sporocarp, constituting the hymenium. The sporocarp is usually of considerable size, forming much the most conspicuous part of the plant, the vegetative mycelium, in fact, being usually concealed in the substratum. The spores in the hymenium all ripen about the same time, and then the sporocarp usually withers away or decays.

It was formerly supposed that the development of a sporocarp was preceded by a fertilizing process, as in most of the Ascomycetes, but sexual organs have been searched for in vain, and there now exists no reasonable doubt that sexuality has disappeared, as we have found it has done from some species of the lower groups.

The Gelatinous Fungi, the Puff-balls, and most of the species popularly known as Toadstools and Mushrooms belong here. They are classified scientifically according to the shape of the sporocarp, the position and character of the hymenium, etc. There is one species, Exobasidium vaccinii, which shows a very simple fructification, consisting of compactly arranged basidia forming a hymenium directly on the surface of the organs which it attacks. The plant is a parasite on the leaves and stems of Vaccinum vitis-idæa. The Basidiomycetes are distributed into three groups: The *Tremellineæ*, the *Gasteromycetes* and the *Hymenomycetes*.

The Tremellineæ have a soft or gelatinous fructification, and frequently no very definite shape, forming thickish wavy or furrowed masses on the surface of objects on which the mycelium feeds, generally on rotten wood. When the spores are ripe, they give to the surface a powdery appearance. The so-called "Jew's-Ear" (Exidia Auricula Judæ), a toughish, gelatinous, reddish-brown Fungus, shaped something like a human ear, belongs to this group. It grows parasitically upon the Elder and Elm. Other species are common on decaying wood.

The Gasteromycetes are distinguished from the rest by the fact that the hymenium is enclosed within the body of the sporocarp. The latter possesses two coats, the outer and inner periderm, and the interior is variously subdivided into compartments, on the walls of which the basidia are borne. In many species the number of spores on each basidium is eight, but in some there is the usual number, four.

The Lycoperdaceæ, the Hymenogastreæ, the Nidularieæ and the Phalloideæ, form the subdivisions of the group. The Lycoperdaceæ include the Puff-balls and Geasters or Earth-stars. The rounded sporocarps of the former produce innumerable brown spores, which are discharged in clouds by the scaling away of the outer periderm, and the rupturing of the inner one. The latter are similar, except that the tough outer periderm separates into regular segments, which flatten out into a star-like form.

The Hymenogastreæ are subterranean fungi, resembling, in their habits, the Truffles. In most of the other species of the group the walls of the chambers, constituting the supporting frame-work for the hymenium, undergo great changes during the development of the sporocarp, for example, in the Lycoperdons the chambers disappear, leaving only a loose frame-work of threads ; but in the species of this group they remain unchanged until the ripening is complete. The spores are finally set free by their decay.

The *Nidularieæ* or Bird's-nest Fungi (see Fig. 526), form cup-shaped sporocarps, which, when ripe, open at the top, exposing several rounded hard bodies, which look something like eggs in a nest. The hard bodies are the spore-bearing chambers which have become isolated in the process of development.

The Phalloideæ are at first rounded, but in development, the peridium, which consists of three layers, bursts and exposes a chambered spore-bearing area which is elevated on a stalk. The hymenium soon becomes a dark-colored and foul-smelling mucilaginous mass in which the spores are inclosed. The spores are scattered by carrion-flies, which are attracted to the plants in large numbers by the smell.

The Hymenomycetes are a numerous and important group resembling each other in the fact that at the time the spores are ripe, the hymenium occupies the outer free surface of the sporocarp, and not its interior. The plants differ much among themselves as respects the shape of the sporocarp and the form and structure of the hymenium, and on the basis of these differences they are classified into the following sub-orders: The *Thelephoreæ*, the *Clavarieæ*, the *Hydneæ*, the *Polyporeæ* and the *Agaricineæ*.

The *Thelephoreæ* are, in their structure, the simplest forms of the group. One of the species, Exobasidium Vaccinii, has already been mentioned. In all the hymenium is smooth. They form incrustations, in some species of irregular, in others of regular form, on logs, the bark of trees, etc.

The *Clavarieæ*, or Club-fungi (see Fig. 529), have cylindrical or club-shaped, simple or branching sporocarps, which may, according to the species, be white, grey, brown or yellow in color. The hymenium occupies the smooth exterior surface, and when the spores are ripe, they communicate to it a dusty appearance.

The *Hydneæ* (see Fig. 530) are distinguished from the rest by the fact that the hymenium consists of prickle-like projections from the surface of the sporocarp. There are many species, some of them having a cap or pileus supported by a central stalk, as in the common Mushroom; sometimes the stalk is attached laterally, and sometimes there is no stalk.

The *Polyporeæ* are characterized by producing a hymenium which consists of straight tubes arranged compactly side by side. On the inner surface of these tubes the spores are borne. The hymenium covers the under surface. Some of the species produce fructifications of large size. In the genus Polyporus, they mostly form lateral, shelf-like projections which are usually sessile, but sometimes stalked. In the genus Boletus (see Fig. 531), there is an expanded cap and a stalk, the latter usually placed centrally. The tough, spongy mycelium of Polyporus formentarius is sometimes used in surgery under the name of Surgeon's Fungus, and, saturated with solution of potassium nitrate and dried, it constitutes what is called German tinder. Polyporus officinalis, a parasite upon the European Larch, has valuable medicinal properties, and Boletus edulis is one among the few of the large genus to which it belongs that is prized for food.

The *Agaricineæ* produce a sporocarp which is commonly expanded and hat-like in form, and in the majority of cases, is supported on a central stalk; but sometimes the latter is inserted to one side of the centre, or in a few species is altogether wanting. The most distinctive features of the group, however, consist in the structure of the hymenium, which is composed of lamelliform bodies, or "gills," as they are often called, arranged in a radial manner on the under surface of the expanded portion of the sporocarp or pileus. Many of the stalked forms are, in the early stage of their development, invested with a membrane called a *velum* or veil, which, at a later period, is ruptured; but its parts usually remain in the mature sporocarp, forming a sheath at the base of the stalk, or a ring around it higher up, or fringing the border of the pileus. Other forms are destitute of the membrane.

The species are numerous, many of them edible, others useless for food, and still others highly poisonous. Some, as the genus Coprinus, produce a very perishable sporocarp, others are hard, leathery and enduring. The genus Lactarius is distinguished from the rest, and from most other thallophytes, by possessing a milky juice.

Among the edible species are Agaricus compestris, A. deliciosus, Cantharellus cibarius, Marasmius oreades, Lactarius deliciosus and Coprinus comatus; and among the poisonous ones, Agaricus muscarius and Lactarius torminosus, rank as the most dangerous.

For further illustration of the group, we may select Agaricus compestris. A mass of mycelium is formed by the germinating spores in the vegetable mould or humus, from which the plant absorbs its food. On this, protuberances of a rounded or nodular form sooner or later make their appearance and rise above the soil. These are the young sporocarps still invested in their membrane. Presently the membrane ruptures, exposing an upright stalk composed of compactly arranged hyphæ, which are continued at the top into the pileus. The latter is convex and nearly smooth above, and the numerous radiately arranged, plate-like gills, cover the concave surface below. The gill surfaces are composed partly of large sterile cells, and partly of basidia, and each of the latter bears two spores. The spores are minute, and the aggregate number produced by a sporocarp is enormous.

In this species a portion of the velum remains as a ring or annulus on the stalk. See Fig. 525, *A*, *B* and *C*.

Figs. 526 to 534, illustrate various species of the higher Fungi.

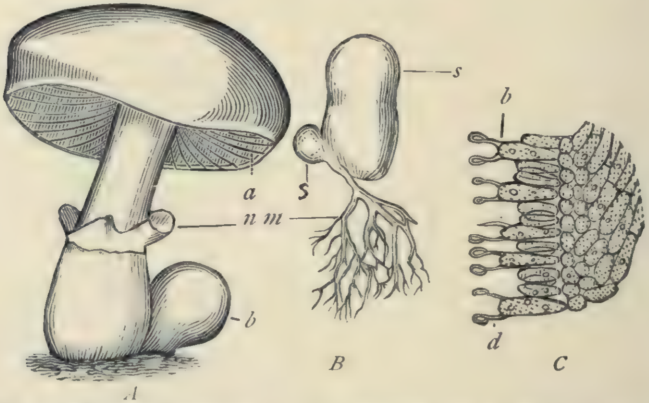


FIG. 525.—Agaricus compestris. *A*, two sporocarps, one of them, *b*, quite young, and still enclosed in its membrane, the other fully matured; *a*, the "gills" or hymenium; *n*, the annulus. Somewhat reduced.

B, young sporocarps, *s*, *s*, of the same species, showing how they originate from the mycelium, *m*.

C, A small portion of one side of one of the gills of the same fungus, showing basidia *b*, and sterigmata, *d*. Magnified about 325 diameters.

FIGS. 526 to 533.—Fungi of various kinds.

FIG. 526.—Cyathus, one of the Nidularieæ or Bird's-nest Fungi, slightly enlarged.

FIG. 527.—Geaster, or Earth-star, nearly natural size.

FIG. 528.—Morchella esculenta, one of the Discomycetes.

FIG. 529.—Portion of Clavaria rugosa, one of the Hymenomycetes.

FIG. 530.—Hydnum repandum, one of the Hymenomycetes, about two-thirds natural size.

FIG. 531.—Boletus edulis, one of the Polyporeæ, about half natural size.

FIG. 532.—Agaricus muscarius, the Fly Agaric, about two-thirds natural size.

FIG. 533.—Marasmus oreades, about two-thirds natural size.

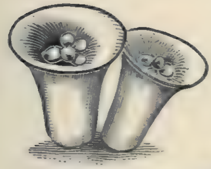


FIG. 526.

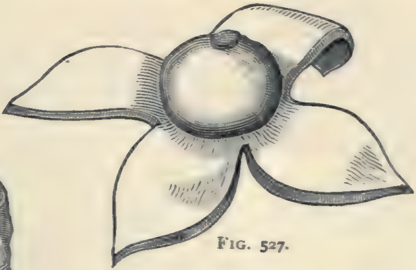
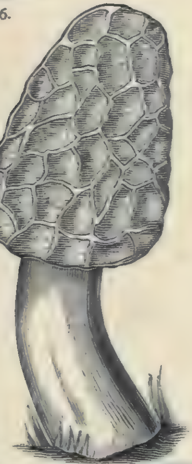


FIG. 527.



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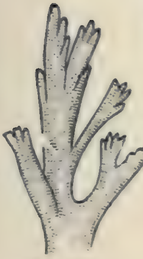

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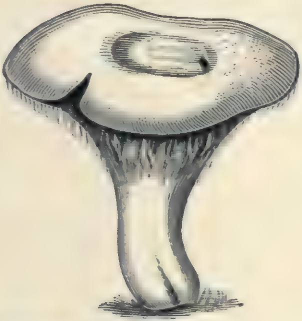

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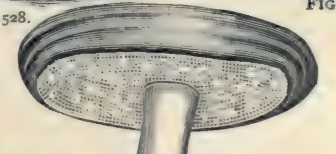

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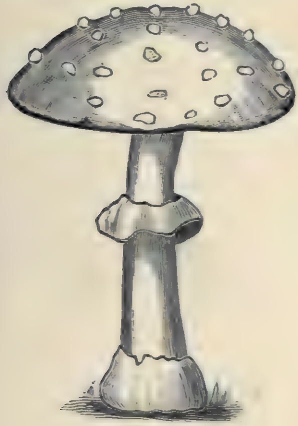

FIG. 532.

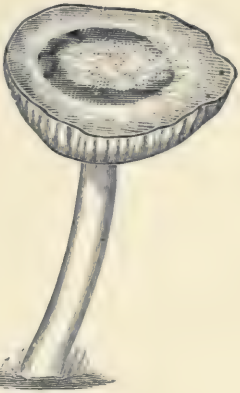

FIG. 533.

[*For description of Figures see preceding page.*]

CHAPTER X.—The Thallophyta (Continued).

CLASS V.—THE LICHENES.

These plants are here treated as a separate Class, more for convenience than because there is anything in their structure which warrants the distinction. They are, in fact, algæ and fungi living together as host and parasite. Each Lichen is a kind of composite organism, a few of the fungi composing them belong to the Basidiomycetes, but by far the larger portion to the Ascomycetes, and in each case the modes of reproduction are such as characterize these groups respectively.

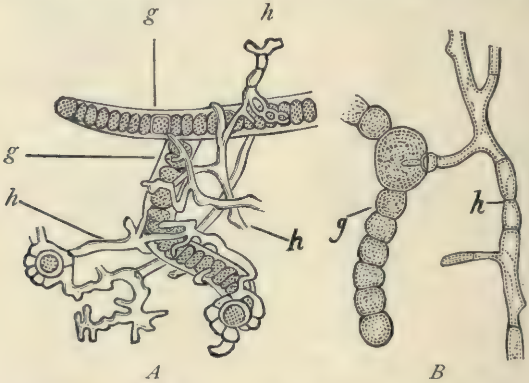

FIG. 534.—Portions of two Lichens, showing fungi parasitic on Algæ. In *A*, the filaments, *g*, *g*, belong to a species of Scytonema and the hyphæ, *h*, *h*, *h*, are those of Stereocaulon ramulosus. Magnification about 950 diameters.

In *B*, a hyphal branch, *h*, is entering the cells of a species of Nostoc, *g*. Magnification about 650 diameters. Both after Bornet.

The algæ mainly belong to the lower forms, such as the Nostocs, the Palmellas, Chroococcus, Chroolepus, and, more rarely, the Confervas; and while they do not lose their power of vegetative multiplication by reason of the parasitism, they do lose the power to reproduce by other means, and moreover, frequently undergo important structural modifications.

The facts are analogous to those which often occur in the higher plants when attacked by fungi or other parasites. The vegetative processes are not destroyed, but in some instances even stimulated, for a time at least, so that over-production or hypertrophy takes place, as when galls are formed by the stings of insects.

Some idea of the character of this association between parasite and host may be gained by the study of Fig. 534 A and B, taken from Bornet's researches on the Lichens. Here portions of tissue from two different Lichens are shown.

But while from the investigations of Schwendener, Bornet, Stahl and others, there can no longer be any doubt as to the composite character of the Lichenes, they nevertheless form a group so distinct in appearance, that their real relationships to Algæ and Fungi were not even suspected until recently.

They are very abundant plants, growing everywhere, on the bark of trees, on fences, decaying logs, rocks, and on the ground. Some form leaf-like expansions ; others closely encrust the surface on which they grow, and others still are fruticose, resembling small branching shrubs in appearance.

Their colors vary from almost white to greenish-gray, yellow, orange or brown. Examined microscopically, their tissues always show colorless filaments, the fungus hyphæ, and green or red chlorophyll-bearing cells which belong to the Algæ. The latter are technically called *gonidia.*

In some species it is the alga element which is the larger factor in determining the shape and structure of the plant ; in the majority, it is the fungus, and the alga is only a subordinate factor. In some Lichens the algæ are equally distributed throughout the thallus ; in others they are arranged in definite groups or layers. The former kinds are described as *homoiomerous*, the latter as *heteromerous.* All the species are capable of enduring dessication without destroying their vitality.

The fructification of Lichens is, as we have seen, that of the fungus and not of the alga. In all those whose life-history has been traced, there are male and female organs of reproduction. The former are roundish or flask-shaped cavities or conceptacles in the thallus called *spermogonia,* which, when ripe and wet with water, emit very numerous minute spermatia from a narrow opening. The archicarp, or ascogonium as it is also called, is at first a thickish hyphal branch which becomes twisted into close coils at its base and remains straight at its apex. The twisted portion becomes the archicarp proper, and the straight portion, which is divided by transverse partitions into several cells, serves as a trichogyne to receive the fertilizing influence of the spermatia, after the manner of the Florideæ. The archicarp remains buried in the tissues of the thallus until after fertilization, but the trichogyne perforates the cortex and comes to the outside.

After fertilization, which takes place when the thallus is wet, the archicarp becomes invested with hyphæ which grow up from below, and the developing fruit is carried to the surface, where it forms an organ called the *apothecium*. This, in all essential respects, is like the fructification of the higher Ascomycetes, having a hymenial surface which bears asci and ascospores. In some species the apothecium spreads out its hymenial surface very much as in the fructification of Peziza; in others, it is closed, and the spores, when ripe, escape from a narrow opening, as in the Pyrenomycetes. Fig. 535 represents a perpendicular section of an apothecium of the former kind.

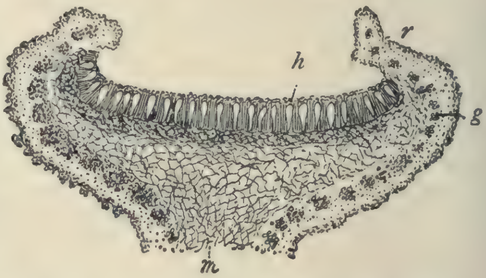

FIG. 535.—Vertical section of apothecium of Anaptychia ciliaris; *h*, hymenium, producing numerous asci; *g*, gonidial layer; *r*, rind, composed of compact hyphæ; *m*, medulla, composed of loosely arranged hyphæ. Magnified about 50 diameters. After Sachs.

Many of the Lichens also multiply asexually by means of *soredia*. These are gonidia, or groups of them, wrapped about with hyphal filaments, which escape from the Lichen thallus, usually in the form of a fine powder, and germinate immediately to form new plants.

According to the structure and mode of growth of the thallus, Lichens are ordinarily subdivided into the following groups:

(A). **The Homoiomerous Lichenes.** The members of this group have for the most part a more or less gelatinous thallus, which is sometimes flattened and lobed, and sometimes filamentous, consisting of a gonidial filament with fungus hyphæ wrapped about it. Their gonidia all belong to the Cyanophyceæ.

(B). **The Crustaceous Lichenes** form a numerous group, having a thallus of indefinite form adhering so closely to the substratum on which they grow, that it is often difficult to distinguish them from it. They grow on rocks, smooth-barked trees, wooden fences, and sometimes on the ground. One, called

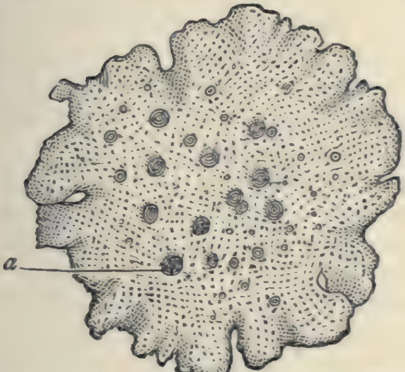

FIG. 537.

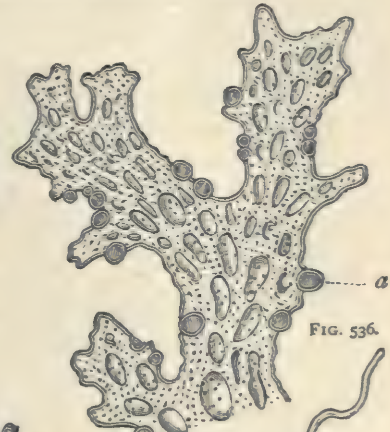

FIG. 536.

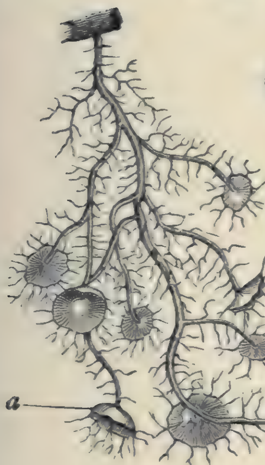

FIG. 538.

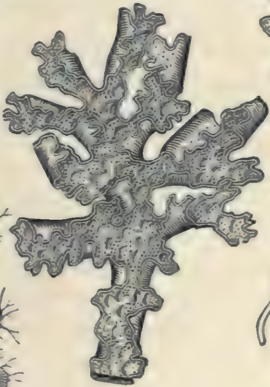

FIG. 540.

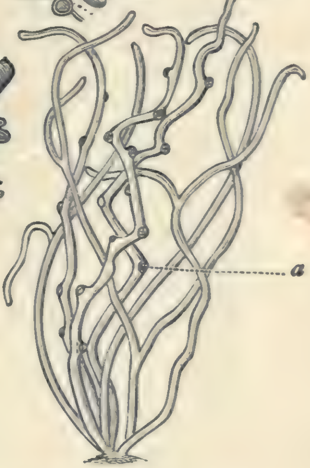

FIG. 539.

FIG. 536.—Portion of thallus of Sticta pulmonacea, a foliaceous Lichen. *a*, apothecium. Natural size.

FIG. 537.—Thallus of Umbilicaria vellea, a foliaceous Lichen. *a*, apothecium. Natural size.

FIG. 538.—Thallus of Usnea barbata, a fruticose Lichen, about natural size. *a*, apothecium.

FIG. 539.—Thallus of Roccella tinctoria, a fruticose Lichen, about natural size. *a*, apothecium.

FIG. 540.—Portion of Cetraria islandica, a fruticose Lichen with a flattened thallus. About natural size.

Graphis scripta, from its fancied resemblance to hand-writing, is common on the trunk of the Beech; and another, Rhizocarpon geographicus, forms a bright yellow incrustation of indefinite extent on granitic and other silicious rocks.

(C). **The Foliaceous Lichenes** form flattened leaf-like expansions, which may be variously lobed or crispate on the margins and adhere, often in the form of rosette-like patches, more or less closely to the substratum. Many of these, as the Parmelias and Stictas, form greenish-grey or yellowish patches on tree-trunks, fences, etc.; others, as the species of Peltigera, grow on damp hillsides among the moss, and bear their apothecia on the lobed borders of the thallus. Still other species, as those of Gyrophora and Umbilicaria, form dark-colored patches on rocks. See Figs. 536 and 537.

(D). **The Fruticose Lichenes** have a shrub-like growth, often branching profusely, and are attached to the substratum only at the base. The branches of the thallus are in some species cylindrical, in others flattened, but even in the latter there is usually little, if any, structural difference between the upper and under surface. For the most part the gonidia are arranged in the form of a hollow cylinder running lengthwise of the branches; the interior of the cylinder is filled with hyphæ, and on the exterior they enclose it as a sheath. Many of the species cling to tree-trunks, logs or rocks, but some grow upon damp earth.

To the forms having cylindrical branches belong the Usneas (see Fig. 538), Roccella tinctoria, a Lichen that constitutes one of the principal sources of Litmus (see Fig. 539), and the familiar Cladonia rangifarina, or Reindeer Lichen; and to those with flattened branches belong the so-called Iceland Moss, Cetaria islandica, prized as a food, and used in medicine for its demulcent and tonic properties. See Fig. 540.

CHAPTER XI.

SERIES II.—THE BRYOPHYTA, OR MOSS PLANTS.

THE HEPATICÆ—THE MUSCI.

- I. Hepaticæ
  - Riccieæ.
  - Anthoceroteæ.
  - Marchantiaceæ.
  - Jungermanniaceæ.
- II. Musci
  - Sphagnaceæ.
  - Andreaceæ.
  - Bryaceæ
    - Acrocarpi.
    - Cladocarpi.
    - Pleurocarpi.

The plants of this Series, on the whole, show, in the more complete differentiation of their cells into tissues and of the plant body into stem, leaves and root-hairs, as well as in their more complicated reproductive process, a decided advance in structure over the members of the preceding Series. At first sight the two groups seem sharply distinct, but a closer comparison shows that there are few points in the Bryophyta which have not been clearly anticipated by some of the plants below them. In turn, the Bryophyta anticipate some of the features of the higher plants.

All Moss-plants are chlorophyll-bearing; in all, the plant body consists of true tissues formed by cell-division; all are of small or moderate size, seldom attaining more than a few inches in height, yet none of them at maturity are so small as to be strictly microscopic; none possess true roots, though many bear root-hairs, corresponding probably to those of the higher plants, by means of which they attach themselves to the substratum or absorb nutriment; a few are aquatic; most are either terrestrial or epiphytic, but none are either parasitic or saprophytic.

All the species are characterized by a distinctly-marked alternation of a sexual with an asexual generation. The plant which bears the sexual organs is the more conspicuous; it may be either a leafy-stemmed plant or a thallus. It does not spring directly from a spore, but the latter, in germinating, first forms a *protonema*, from which the leafy or thalloid plant is subsequently developed.

In the majority of the Bryophyta, the distinction between leaf and stem is clearer than in the Characeæ and other foliose Thallophyta, but the leaves of Mosses are simpler in their structure than those of higher plants. They often consist of a flat expansion composed of a single layer of cells which are all alike, but in a few species the cells are in more than one layer and one or two simple nerves are developed. The stems, of the higher forms at least, have an axial bundle of elongated, thin-walled

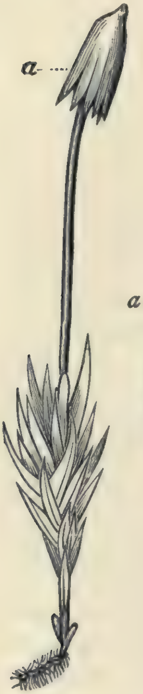

FIG. 541.

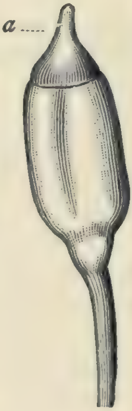

FIG. 542.

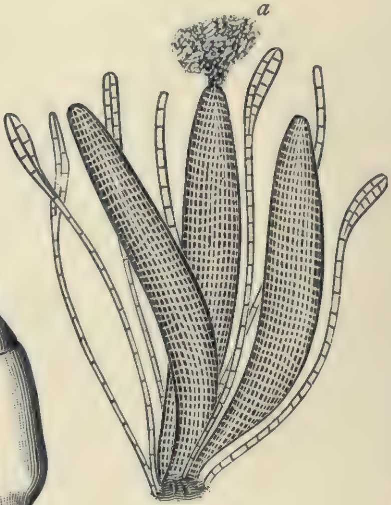

FIG. 543.

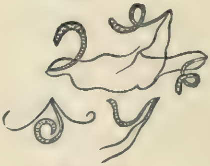

FIG. 544.

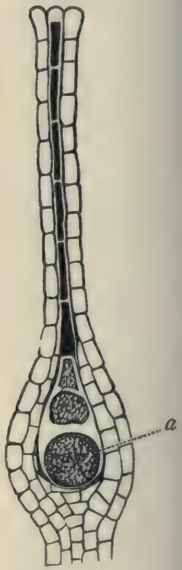

FIG. 545.

FIG. 541.—The common Hair-cap Moss, Polytricum commune, in fruit. *a*, stalked capsule covered with a calyptra.

FIG. 542.—Capsule somewhat magnified, and with the calyptra removed, showing operculum, *a*.

FIG. 543.—Paraphyses and antheridia, one of the latter emitting antherozoids, *a*.

FIG. 544.—Antherozoids, highly magnified.

FIG. 545.—Female organ, or archegonium, highly magnified. *a*, oösphere.

cells which must be regarded as anticipating the fibro-vascular bundles of the higher plants, though true vessels are never developed.

Mosses differ from most of the higher plants in their branching. The thalloid forms mostly branch dichotomously, and the branches of the foliose forms do not spring from the leaf-axils, but from the side of the leaf, or from a point below it. The stems increase in length by means of a single terminal cell, and in many cases the plants continue to grow at the apex, while dying away at the base.

The organs of reproduction consist of *antheridia* and *archegonia.* These are sometimes borne solitary on the stem or thallus, but more commonly in groups; sometimes both kinds of organs in the same group, sometimes the different kinds in distinct groups. They are often closely associated with hair-like bodies, called *paraphyses*, and are not infrequently surrounded with slightly modified leaves, called the *perichætium* or the *perigynium.*

The antheridia are short-stalked, multicellular bodies, spherical, oblong, ovate or club-shaped in form, and produce in their interior cells multitudes of minute, slender, spirally-coiled, biciliated antherozoids. The latter are thicker at one end, and it is to the opposite end that the cilia are attached. (See Figs. 543 and 544.)

The archegonia are flask-shaped, multicellular bodies, with a narrow, elongated neck, and a relatively thick, rounded base. They possess at first an axial row of cells, the one in the dilated base being of larger size than the rest, and constituting the germ-cell. Later, the axial cells of the neck dissolve into mucilage, through which the antherozoids penetrate to the germ-cell. The former are discharged from the antheridia when moisture is present, and it is through the medium of the water that they find their way to the archegonia. (See Fig. 545).

The fertilization thus effected initiates an important series of changes resulting in the production of the plant of the asexual generation, very different in appearance from the sexual plant, but growing up in contact with it, and technically called the *sporogonium.* The process of development is as follows: The fertilized germ-cell, still enclosed within the archegonium, divides repeatedly in different directions, and the lower portion of the cell-mass thus formed penetrates the tissues of the parent plant, and the rest develops outward, stretching, and finally rupturing the walls of the archegonium, which, immediately after fertilization, usually increases considerably in size, and then stops growing, while the sporogonium continues its development. As this proceeds, the basal part usually develops into a stalk, sometimes of considerable length, while the apical portion swells into a capsule, which produces in its interior multitudes of minute spores. See Fig. 546.

The archegonium, in some species, is ruptured at its apex by the growth of the sporogonium, and then its torn remains are seen as a kind of sheath at the base of the stalk ; in others, and more commonly, it ruptures near the base, and then is borne like a cap, called the *calyptra*, at the top of the capsule. See Fig. 541, *a*.

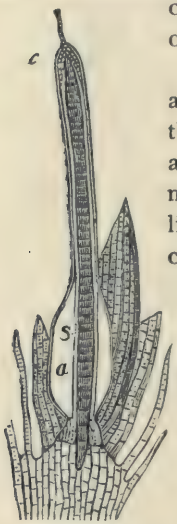

FIG. 546.

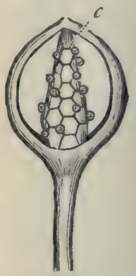

FIG. 547.

FIG. 546.—Development of sporogonium of Funaria hygrometrica. *a*, archogonium already much stretched by the development of the sporogonium, *s*, the lower part of which has penetrated the tissues of the stem, and the upper part of which carries the calyptra, *c*. Magnified about 50 diameters. After Sachs.

FIG. 547.—Capsule of Phascum muticum cut open so as to show the columella, *c*, to which a few spores are still attached. Magnified.

The capsules, when ripe, differ in structure and mode of dehiscence, in ways which are more or less characteristic of the genera. In some, there is developed in the interior of the capsule an axial organ, called a *columella*, around which the spores are borne (See Fig. 547) ; in others, no such organ is present. In the capsules of some there are developed among the spores peculiar filamentous, usually spirally coiled, bodies, called *elaters*, which aid in the ejection of the spores after the capsules are ripe ; in other species elaters are wanting.

In some species, the capsule splits, when ripe, longitudinally into two or four valves ; in others, the dehiscence is transverse and the upper part, called the *operculum*, comes off like a lid ; in a few forms the dehiscence is irregular, and rarely there is none at all, but the spores are set free by the decay of the capsular walls.

The spores are minute cells with the wall differentiated into two parts, a thicker outer coat, called the *exospore*, and a thinner interior one, which is very distensible, like the inner coat of a pollen-grain, called the *endospore*. In germinating, the exospore ruptures, and the endospore becomes distended into a tube, which usually divides transversely and forms a mass of green, branching filaments, which resemble some of the filamentous algæ; this is the *protonema*, from which either directly or by production of lateral buds, the plant of the sexual generation is developed. See Fig. 548.

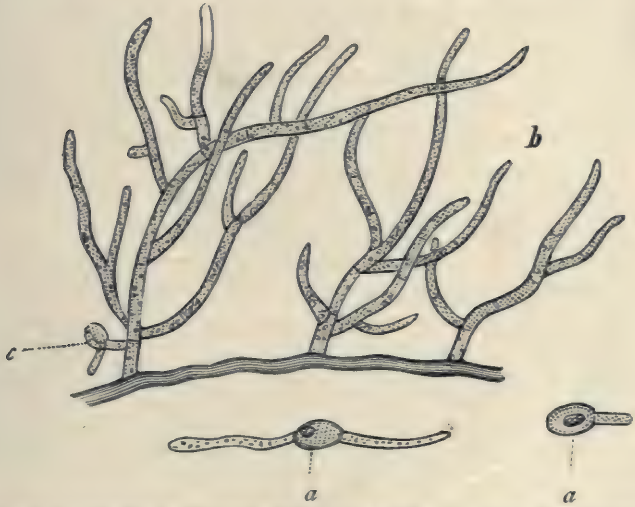

FIG. 548.—Germinating spores and protonema of Moss. *a*, *a*, spores in different stages of germination; *b*, filaments of the protonema; *c*, bud on protonema destined to develop into a leafy plant. Magnified about 550 diameters.

The Series is subdivided into two Classes, the *Hepaticæ* and the *Musci*.

CLASS I.—THE HEPATICÆ (LIVERWORTS).

The Hepaticæ, or Liverworts, are the lower in organization. They include many thalloid forms, and the leaf-bearing or foliose ones present a simpler structure than the Mosses, proper. Their capsules, if they dehisce at all, open lengthwise, usually into four, but sometimes into two, valves. Except in one order, the Anthoceroteæ, they do not possess a columella. Most of the species are provided with elaters. The remains of the archegonium are never borne on the top of the capsule.

In habit of growth, nearly all of the species lie prostrate on the substratum, presenting one side to the light and having the other in shade. The two surfaces accordingly have a different structure, rhizoids being usually developed in great numbers on the shaded but not on the illuminated side; the latter, in the thalloid forms, also often possesses stomata, while the other does not. The flattened forms usually branch dichotomously, and in some of these there is no indication of leaves, while in others, as in the Marchantias, scale-like bodies, doubtless to be regarded as imperfectly developed leaves, occur on the under surface.

In the foliose forms, there are two vertical rows of leaves, very simple in their structure, on opposite sides of the stem, and usually a third row of less perfectly developed ones on the side next the substratum.

There are four orders, as follows:

(A) **The Riccias** are thalloid forms which branch dichotomously, and produce their antheridia and archegonia singly on the upper side of the thallus. The capsule is globose, either unstalked or short-stalked, does not bear elaters, and does not spontaneously rupture when ripe. The plants are of small size, and not numerous in species. Some of them, as Riccia fluitans and R. natans, are not uncommon in fresh water; others, as Riccia glauca, grow on damp soil.

(B) **The Anthoceroteæ** produce a flattened, irregularly-lobed thallus, which is closely attached by means of rhizoids to the damp soil in which they grow. They produce erect, pod-like capsules from archegonia imbedded in the upper surface. These dehisce lengthwise into two valves exposing a columella. The elaters in this group do not consist of coiled threads or bands, as they do in the succeeding orders of this class. The species are not numerous. Anthoceras laevis, one

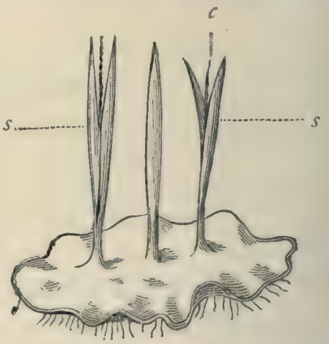

FIG. 549.—Anthoceras laevis. Portion of thallus showing sporogonia, *s*, *s*, dehiscing into two valves; *c*, columella.

of the most commonly observed species, is illustrated in Fig. 549.

(C) **The Marchantiaceæ** have thalloid, dichotomously branching stems, producing numerous well-developed stomata on the upper surface, and abundant rhizoids and two rows of small scale-like leaves on the lower. The antheridia and archegonia are borne in separate, stalked receptacles. The capsules dehisce variously in different species, sometimes by four valves and sometimes irregularly, and the ejection of the spores is aided by spirally-coiled elaters.

Marchantia polymorpha is found everywhere on damp ground, on wet rocks adjacent to springs and waterfalls, and on the damp earth of green-houses. Fig. 550, *A*. represents a portion of a thallus, bearing an erect, stalked, wheel-shaped receptacle, *a*, in the upper surface of which numerous antheridia are imbedded. Fig. 550, *B*, represents a portion of a stem of the same species, bearing a female receptacle which consists of a star-shaped body borne at the summit of an erect stalk. On its under surface, near the base of the rays, when the organ is young, are borne the flask-shaped archegonia, and at a later stage, there are developed in their place rounded, short-stalked sporogonia. Sessile, cup-shaped receptacles producing gemmæ, small rounded or oblong, cellular bodies, by means of which the plant is

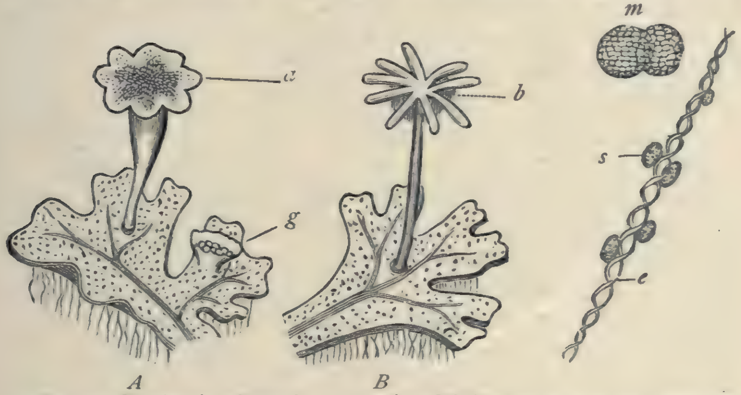

FIG. 550.—Marchantia polymorpha. *A*, portion of thallus bearing a stalked receptacle, *a*, producing antheridia. *B*, portion of thallus bearing a stalked receptacle, *b*, bearing sporogonia on the under surface of the rays; *g*, one of the receptacles with gemmæ; *m*, one of the gemmæ magnified; *e*, elaters highly magnified, and *s*, a spore clinging to the elaters.

reproduced vegetatively, also occur in abundance on the upper surface of the branches. One of these, and one of the gemmæ magnified, are shown in Fig. 550, *g* and *m*.

(D) **The Jungermanniaceæ** constitutes the largest order of the Hepaticæ. A few of them have thalloid, but the great majority, foliose stems. They produce solitary capsules which ordinarily split into four valves, from the apex downwards, and produce numerous spores and spiral elaters.

Among the leafless forms are Blytia, Pellia, Aneura, Blasia, and Metzgeria. Metzgeria furcata has a dichotomously-branched, narrow thallus composed of a single stratum of cells, except the midrib, which includes several layers. It is not uncommon on tree trunks in damp woods. In most of the thalloid forms, the archegonia are produced on the upper surface and not at the apex of the thallus.

In the foliose forms the leaves occur, as has already been described, in three longitudinal rows, and two of the rows are conspicuous and spread out laterally, while the third occurs on the shaded or under side, and its members are not so well developed. The fruits occur singly on stalks at the ends of the branches. See Fig. 551. Many of the species are common in damp soil and on tree trunks. They are plants of wide distribution, occurring both in the northern and southern hemispheres. *Jungermannia*, *Calypogeia*, *Geocalyx*, *Gymnomitrium* and *Pleuranthe* are among the genera.

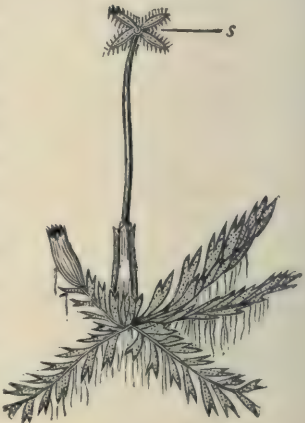

FIG. 551.—Jungermannia bidentata. *s*, sporogonium dehiscent into four valves.

CLASS II.—THE MUSCI (MOSSES).

The Musci or Mosses are all leafy-stemmed plants, and the leaves are all of the same kind and very seldom two-ranked. The spores produce a confervoid protonema which may increase indefinitely by an apical growth, but sooner or later gives rise to lateral buds which develop into the leafy plant. See Fig. 548. When the germ-cell develops in the archegonium, the latter usually ruptures at the base, and is carried up as a calyptra on the top of the capsule. In the great majority of cases the latter has a circumscissile dehiscence, and the operculum comes off like a lid. The columella is always present, and the capsule never produces elaters.

There are three orders of Mosses, as follows:

(A) **The Sphagnaceæ** or Bog-mosses, grow in tufted masses in boggy places, about springs and along the banks of mountain brooks, where the supply of water is constant; they have a pale-green, or sometimes a purplish color, straight stems, with numerous laterally spreading, fascicled branches, which are covered with closely imbricated leaves. The latter are nerveless and consist of a single layer of cells, but these are of two kinds, one large, colorless, perforated by pores and lined with spiral or annular filaments, and the other narrowly linear, chlorophyll-bearing, and forming a net-work around the former kind. The antheridia are borne on club-shaped or catkin-like, usually colored branches, and the archegonia are commonly in groups of three or four enclosed in a bud-like involucre at the ends of short branches. The capsule is round and operculated, but without a peristome, and pedicelled, but the pedicel, instead of being a part of the sporogonium, as is usually the case in other mosses, is a prolongation of the axis of the sexual plant. The remains of the archegonium are found at the base of the capsule, and not as a cap or calyptra at the top.

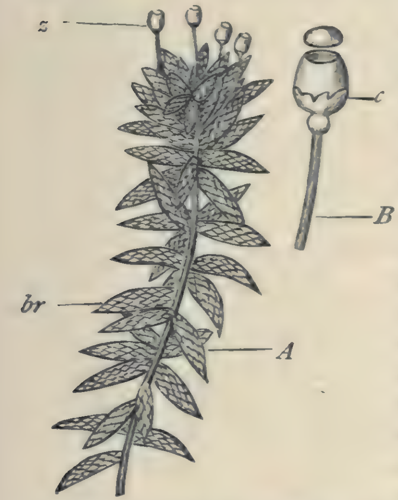

FIG. 552.—Sphagnum cymbifolium. *A*, mature plant-bearing leafy branches, *br*, and capsules, *z*. *B*, one of the capsules, considerably magnified, showing operculum; *c*, is the remnant of the wall of the archegonium.

The Sphagnums are the peat-forming mosses, and are largely confined to the cooler portions of the globe. One of these mosses is illustrated in Fig. 552, *A* and *B*.

(B) **The Andræaceæ.** This is a small order of dark colored, branching mosses, of rather diminutive size, mostly growing on damp rocks in mountainous regions. They produce capsules which have a closely adherent, thin calyptra, and a central columella, which is free at the apex; they dehisce longitudinally into four or rarely six valves. These separate in the middle to shed their spores, but remain united both at the base and apex. See Fig. 553. The capsules are stalked, but the stalks are formed as in the Sphagnums.

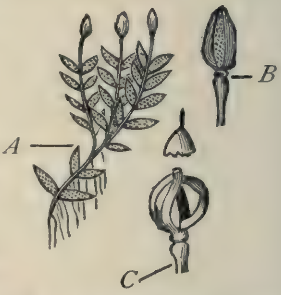

FIG. 553.—Andræa. *A*, fruiting plant: *B*, capsule, magnified; *C*, dehiscent capsule and calyptra.

(C) **The Bryaceæ** constitute by far the largest as well as the best developed order of Mosses. It is one of this order that is illustrated in Figs. 541 to 545, inclusive. They are usually low, tufted plants, with generally cylindrical or rarely slightly compressed or somewhat angular, leafy stems. The leaves are simple, and, in some species, composed of but one stratum of cells; in others, of more than one; in some, the leaves are nerveless, in others there is a single median nerve, and in still others two small nerves at the base.

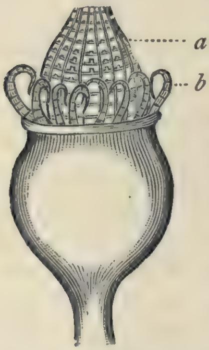

FIG. 554.—Capsule of Fontinalis, one of the Bryaceæ, with calyptra and operculum removed, showing the double peristome; *a*, inner, *b*, outer peristome. Magnified.

The reproductive organs are, in most cases, enclosed in a perichætium or perigonium; the capsule is traversed perpendicularly by a columella which is attached both above and below; in a very few species the capsule either does not open at all or breaks irregularly; in the great majority it dehisces by means of an operculum. The orifice thus exposed is sometimes naked, but in most cases has a *peristome*. The latter may either be single or double, having one part within the other. The outer peristome consists of a row or circle of teeth which, in different species, vary in number from four to thirty-two or more. The inner peristome, if present, consists of a yellowish pellucid membrane, which is often latticed, and attached to the inner base of the outer peristome, and is itself segmented or toothed at the top. See Fig. 554.

There are three subdivisions:

(*a*) The *Acrocarpi* have erect stems and bear the fructification at the apex. To this group belong the Phascums, Dicraniums, Leucobryums, Funarias, Bartramias, Bryums, and many other common Mosses.

(*b*) The *Cladocarpi* bear their fruits on short lateral branches. They are aquatic Mosses, and include but two genera, Fontinalis and Dichelyma.

(*c*) The *Pleurocarpi* bear the fruit laterally in the leaf-axils, either of the main stem or on the branches. They include the Leptodons, Neckeras, Fabronias, Climaciums, Hypnums, and several other genera.

CHAPTER XII.

SERIES III.—THE PTERIDOPHYTA, OR VASCULAR CRYPTOGAMS.

PRINCIPAL DIVISIONS.

- I. Equisetineæ.
- II. Filicineæ
  - Filices.
  - Rhizocarpeæ.
- III. Lycopodineæ
  - Lycopodiaceæ.
  - Psilotaceæ.
  - Ligulatæ
    - Selaginelleæ.
    - Isoëteæ.

The Pteridophyta, like the preceding series, consist entirely of chlorophyll-bearing plants, which are never either parasitic or saprophytic. The word "Pteridophyta" literally means "fern-plants," the Ferns being the most numerous as well as the most important members of the Series.

The term "Vascular Cryptogams" is applied because here, for the first time, we find a distinct development of ducts and other vessels which are the result of cell-fusions. In many of the species, in fact, we find a differentiation of tissues almost as complete as that found in flowering-plants. Moreover, in the plant-body all the organs of vegetation, root, stem, leaf and plant-hair or trichome, are fully represented.

In the reproductive process, also, great progress is shown over that which occurs in the Mosses. They exhibit, like the Bryophyta, a distinct alternation of generations, but while in the latter group the sexual plant is the more conspicuous and better developed, the reverse is the case in the Pteridophyta, the plant producing the sexual organs being, even in those species in which it is best developed, a mere thallus resembling that of some of the lower Hepaticæ, and commonly perishing soon after the fertilization of the germ-cell has been effected, while the asexual plant developed from the latter, is conspicuous and highly organized.

The process of reproduction, briefly outlined, is as follows: The spore borne by the asexual plant germinates and produces the sexual plant, which since it is temporary in its character, a mere forerunner, so to speak, of the plant which is ultimately produced by it, is called a *prothallium*.

In the Ferns, Equisetums and other species in which it is most highly developed, it consists of a flattened body attaching itself to moist soil by means of hairs emitted from the under surface, and is always insignificant in size compared with the plant which produced the spore. It is composed of chlorophyll-bearing cells, and may continue its growth for some time before bearing fructifying organs. These consist of antheridia and archegonia. The archegonia, like those of the Mosses, are flask-shaped, cellular structures, having an enlarged basal portion which contains the germ-cell or oösphere, and a neck through which the fertilizing cells penetrate. The basal portion is buried in the tissues of the thallus, but the neck is free, projecting above the surface. The latter is usually short and composed of four longitudinal rows of cells.

In the interior of the young archegonium, an axial row of three cells is formed, the lower constituting the oösphere, the other two the neck cells, which later are converted into mucilage, the pressure of which forces apart the cells composing the wall of the neck, forming a passage for the antherozoids. The mucilage which oozes out of the opening seems to have an important influence also in directing the antherozoids to their destination.

The antheridia may be produced on another part of the same prothallium, or on a different one. They are usually rounded cellular bodies, with walls composed of a single layer of cells, and borne on the surface of the prothallium. In the interior a number of small rounded cells are produced, each of which emits a spirally coiled antherozoid, provided at its anterior or smaller end with numerous vibratile cilia. Both organs are usually borne on the under surface of the prothallium, and the antherozoids are set free when the surface is bathed in water, and through this medium they swim about, finding their way ultimately to the mucilage discharged at the orifice of the archegonium, and penetrate through it to the germ-cell. The latter now begins to develop in the bottom of the archegonium, and by means of a root-like process which it sends into the tissues of the prothallium, it for a time derives nourishment from it, but soon forms roots, stems and leaves of its own, and becomes independent.

In the Mosses, under the same circumstances, only a sporgonium, which remains attached to the parent plant, and seems a part of it, is produced; but here it develops into a conspicuous and highly organized plant, usually with an unlimited period of growth, and possessing roots, stem and leaves. This plant at maturity bears, usually either on the ordinary leaves, or on others specially modified for the purpose, a multitude of spores corresponding to those produced in the capsules of Mosses. These are borne in organs called *sporangia*, which may be regarded as modified hairs.

Great differences exist in different members of the Series, in the degree of development which the prothallium attains. In the Ferns, and other of the lower members of the group, it is comparatively well developed, while in some of the higher forms it tends to disappear entirely, being reduced to one, or a very few cells, which do not emerge from the coats of the germinating spore.

Some of the species produce but one kind of asexual spores, while others produce two sets, one of large size, called *macrospores*, which, in germinating, produce prothallia bearing archegonia only, and a smaller, called *microspores*, whose prothallia produce antheridia only. The former species are called *isosporous*, the latter, *heterosporous*.

Three distinct classes are usually recognized: (1) the *Equisetineæ*, (2) the *Filicineæ*, and (3) the *Lycopodineæ*.

CLASS I.—THE EQUISETINEÆ, OR HORSETAILS.

The plants of this Class are readily distinguished by their hollow, cylindrical, jointed and fluted stems, their sheath-like whorls of united leaves, and their terminal, cone-like fructifications. The internodes of the stem are hollow, but each node is closed by a membrane; the leaf-sheath is broken up into a number of points at its apex, each point corresponding to the tip of a leaf, and for each there is a corresponding fibro-vascular bundle, which at the base of the sheath passes into the stem, thence straight down it to the node next below, where it forks into two, the branches coalescing with those of the stem.

The stems are all herbaceous and mostly perennial, from creeping, underground stems; the aerial stems usually perish at the close of the season, but a few, like those of the scouring-rush, Equisetum hyemale, persist over winter. The stems are sometimes simple; sometimes they are branching, and the branches, which have their origin on the inside of the base of the leaf-sheath, are arranged in whorls. The stems grow from a terminal, triangular-pyramidal cell.

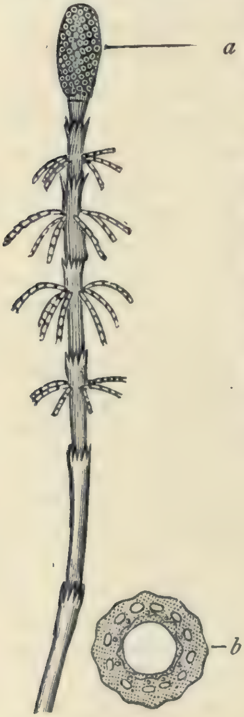

FIG. 555.

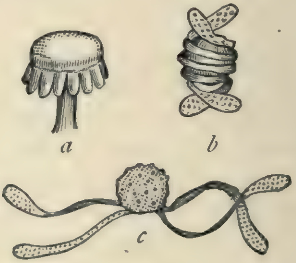

FIG. 556.

FIG. 555.—Portion of Equisetum sylvaticum, showing fruiting cone, *a*, at the apex of the stem; *b*, transverse section of stem somewhat magnified.

FIG 556.—Equisetum sylvaticum, *a*, fruiting scale, magnified, showing sporangia; *b*, one of the spores enveloped in the elaters; *c*, one of the spores with elaters extended.

The fruiting cone is either borne on the ordinary vegetative stem, as in Equisetum hyemale, or on a special stem of a little different form set apart for the purpose, as in Equisetum arvense.

It consists of compactly arranged whorls of modified leaves, each of which is a flattish, usually hexagonal scale, elevated centrally on a short stalk, and bearing around its interior margin the sporangia. The spores produced in the latter are provided with elaters, which being hygroscopic, coil and uncoil as the amount of moisture present increases or diminishes, the movements aiding the ejection of the spores from the sporangia. See Figs. 555 and 556.

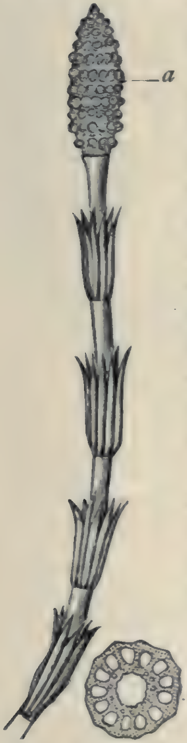

FIG. 557.—Fruiting plant of Equisetum arvense; *a*, fruiting cone; *b*, transverse section of stem, showing hollow and circle of fibro-vascular bundles and large intercellular spaces.

All the existing species of Equisetums are isosporous, though there is good reason to believe that in some of the fossil members of the class two kinds of spores were produced. Most of the living forms are practically diœcious, some of the spores producing male and others female prothallia. This, however, is probably not due to any inherent difference in the spores but to difference of nutrition, the prothallia which are well nourished producing archegonia only or mainly, while those which receive a deficient supply of nutriment bear antheridia only.

The forms of the prothallia in the Equisetums are usually more irregular than those of Ferns, commonly developing lobes or processes of various sizes. The antheridia are apically or marginally situated, and the archegonia, though first formed on the margin, on account of the continued growth of the prothallium, come to occupy the upper surface. The antherozoids are of much larger size than those of the Ferns. In other respects, the mode of sexual reproduction in these plants closely resembles that of the Ferns, presently to be described more in detail. Fig. 557 represents a fruiting plant of Equisetum arvense, a species common in damp, sandy soil, and which produces from its rhizomes chlorophylless, simple stems that mature their spores early in the spring and then die, and later develop freely branching green stems that continue to grow during the season.

Figs. 558 and 559 show, respectively, male and female prothallia of this plant.

The forms of Equisetineæ, at present in existence, are all included under the one genus Equisetum, and this does not contain a large number of species; the individuals, however, are abundant and widely distributed. Some of the species are remarkable for the large amount of silica contained in the epidermis.

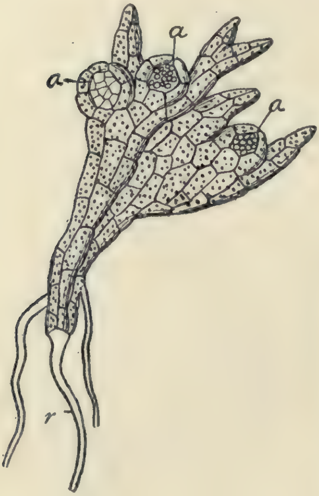

Fig. 558.

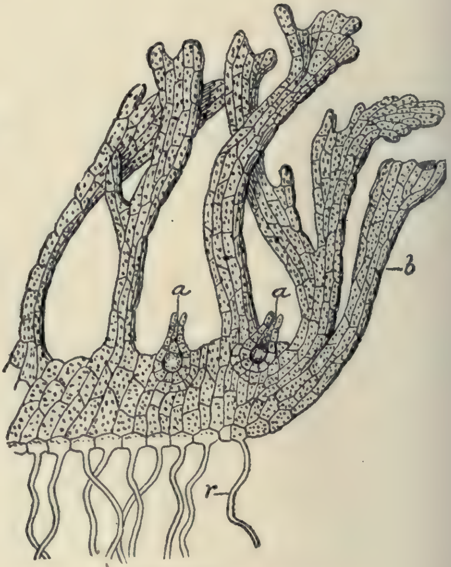

Fig. 559.

Fig. 558.—Male prothallium of Equisetum arvense; *r*, rhizoid; *a, a, a*, antheridia in various stages of development. Magnified about 300 diameters.

Fig. 559.—Part of female prothallium of Equisetum arvense. *a, a*, archegonia; *b*, branch of prothallium; *r*, one of the rhizoids. Magnification about 300 diameters.

CHAPTER XIII.—THE PTERIDOPHYTA (CONT'D).

CLASS II.—THE FILICINIEÆ, OR FERNS.

These are plants with solid, mostly unbranching, or but sparingly branching stems, which, in our species, are all subterranean; but in some tropical or sub-tropical forms rise above ground and form scaly trunks, sometimes of considerable size. They all increase in length by the division of a single apical cell.

The leaves are more highly developed than in any other group of vascular cryptogams. They are ample, petioled, sometimes stipulate, and commonly, though not always, fork-veined; they usually unfold circinately, increase in length by an apical growth, and often branch into very compound forms.

The fibro-vascular bundles are of the concentric type, and of that variety of it which has the xylem tissues located centrally, and ensheathed by the phloëm. In the stems the bundles are usually disposed in a single circle, as has already been explained. See Vegetable Histology.

The sporangia are always borne on the leaves, either on those of the ordinary form, or on those slightly modified for the purpose. They are either borne at the margins or on the under surface, most commonly in groups or clusters, each called a *sorus*. The sporangia are cellular sacs, whose walls consist of a single layer of cells, and enclose usually a considerable number of spores.

The class is subdivided into two groups, those which produce but one kind of spores, and those which produce two kinds, isosporous and heterosporous Filicineæ. The former is represented by one order, the *Filices*, or true Ferns, and the latter also by one, *Rhizocarpeæ*, or Pepperworts.

Order A. Filices. This constitutes by far the largest order of vascular cryptogams, and includes all the plants we ordinarily call Ferns. The spores in germinating produce at first a filament, one end of which soon expands into a flattened tissue consisting of one stratum of cells. By further growth it becomes two-lobed or cordate at the apex, the growing point being located between the lobes, and the middle portion of the prothallium becomes several layered. The organ is usually better developed and longer lived than in other vascular cryptogams. Except in the Ophioglossums, where it is subterranean in its habit and consists of a mass of chlorophylless cells of indeterminate shape, it is a flat, green thallus, attached by one surface to the soil by means of numerous simple root-hairs.

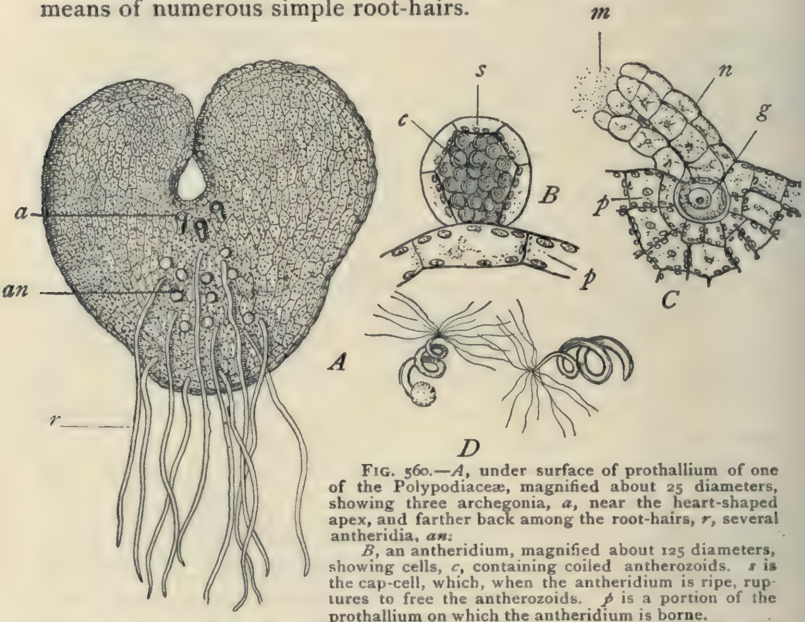

FIG. 560.—*A*, under surface of prothallium of one of the Polypodiaceæ, magnified about 25 diameters, showing three archegonia, *a*, near the heart-shaped apex, and farther back among the root-hairs, *r*, several antheridia, *an*:

B, an antheridium, magnified about 125 diameters, showing cells, *c*, containing coiled antherozoids. *s* is the cap-cell, which, when the antheridium is ripe, ruptures to free the antherozoids. *p* is a portion of the prothallium on which the antheridium is borne.

C, is a ripe archegonium, also magnified about 125 diameters. *p*, portion of prothalium in which the base of the archegonium is imbedded; *g*, germ-cell; *n*, neck of archegonium, consisting of four rows of cells; *m* mucilage discharged from neck.

D, antherozoids, magnified about 500 diameters.

The sexual organs of both sorts are borne on the inferior surface. The antheridia are rounded bodies usually produced in abundance at the margin and on the posterior surface of the prothallium among the root-hairs. In the majority of cases they consist of a single layer of cells enclosing other cells, which, by division form the antherozoids. The antheridium when ripe absorbs water, which causes it to burst at the apex, and the cells containing the antherozoids are set free. Soon after, the walls of these cells burst, each setting free an antherozoid which is coiled like a cork-screw, and provided at its thinner end with numerous cilia.

The archegonia are usually borne near the growing or heart-shaped end of the prothallium. They are flask-shaped bodies with necks rather short, and curved backward or toward the base of the prothallium. See Fig. 560. The mode of fertilization and the development of the asexual plant from the fertilized germ-cell, are essentially the same in the entire class. It has already been described at the beginning of this chapter.

The stems in a few instances, as in Pteris aquilina, have the internodes rather long and not covered by the persistent leaf-bases, but, in most instances, the nodes are crowded together, and the leaf-bases completely obscure the stem, giving it a scaly appearance.

The leaves often bear hairs which are usually flattened and sometimes conspicuous for their size, forming a brownish chaff which, not infrequently, as in the Male Fern, completely invests the young leaves. They are technically called *paleæ*.

The sori, in their arrangement, usually bear a definite relation to the venation of the leaves, and as this is different in different groups, it affords an important means of distinguishing genera and species. For example, in Pteris they are borne on the lower margin along the terminations of the veins, and are protected by the revolute margins of the leaf; in Hymenophyllum, they occur on prolongations of the veins; in Polypodium, they are on the under surface at the extremities of short veins; in the Marattias, they are borne on a kind of cushion which is an outgrowth from the surface of a vein; and in Acrostichum, they occur anywhere on the lower surface, sometimes covering the greater portion of it.

In some species the sori are naked, that is, not enclosed by a protecting membrane, but in many such a membrane is present, and its form and structure often affords characters by which groups are distinguished. In the Shield-ferns, for example, it is a shield or kidney-shaped membrane; in the Aspleniums it has one edge attached to a vein while the other is free; and in some of the Cyatheaceæ it is capsular and completely encloses the sporangia.

The sporangia themselves differ considerably in different groups. In the Polypodiaceæ, the sub-order to which most of our common ferns belong, it has the structure represented in Fig. 561, B. The upper part, or sporangium proper, has a row of thick-walled cells, *a*, which begins at the upper part of the stalk, *s*, on one side and passes vertically over to the other side, but terminates at *d* before it again reaches the stalk. This row of cells is called the *annulus*, and it is at or near where it terminates that the sporangium ruptures when ripe. The dehiscence is transverse, and the spores are ejected by the elastic straightening of the annulus. In this group, as we have seen, the annulus is incomplete, that is, it does not pass completely around the sporangium; in the Hymenophyllums and in the Cyathaceæ, however, it is complete. In some other species, as in the Osmundas, it is wanting entirely, and in the Gleicheniaceæ the sporan-

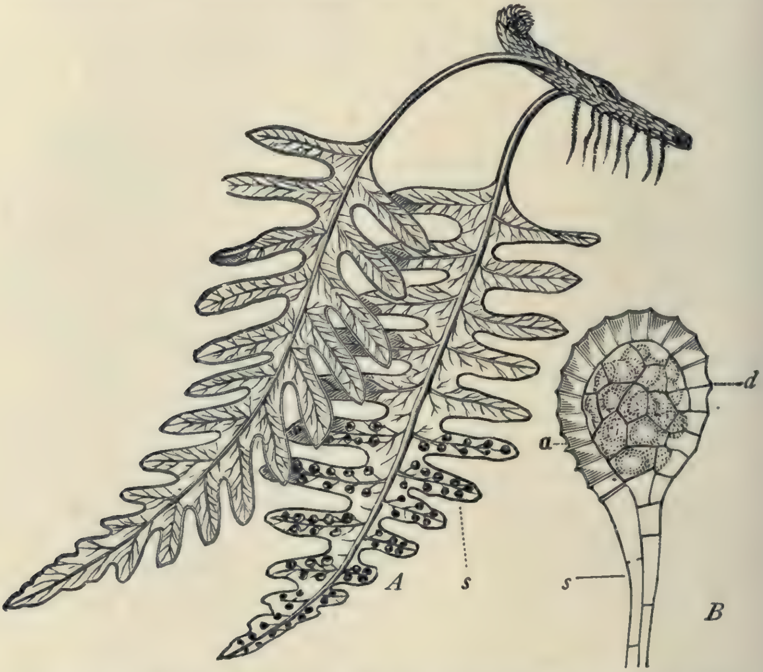

FIG. 561.—Polypodium vulgare. *A*, rhizome and two leaves, one showing the inferior surface and sori; *s*, is one of the sori. *B*, a sporangium of one of the Polypodiaceæ *a*, annulus, composed of thick-walled cells extending vertically around the sporangium to *d*; near *d*, the dehiscence begins: *s*, stalk of the sporangium.

gia are unstalked, provided with an annulus that runs transversely and dehiscence takes place longitudinally. In the Marattiaceæ the sporangia constituting a sorus grow together, forming a compound sporangium, and in Ophioglossum the sporangia occupy cavities in the interior of the leaf near its margins. See Fig. 562.

Order B. The Rhizocarpeæ or Pepperworts. In this order the spores are of two kinds, borne in separate sporangia. Some produce single, large macrospores; others, much smaller microspores in considerable numbers. Both kinds of spores produce very rudimentary prothallia which project but little from the wall of the germinating spores. Those developed from microspores produce antherozoids only, while those which are developed from macrospores produce archegonia only.

The order is a small one, consisting of two sub-orders, the Salviniaceæ and the Marsiliaceæ, each represented by but a few species.

In the Salvinias, the microspore, in germinating, produces a short filament composed of three cells; the one at the apex, and the one just back of it, are shorter than the basal one. The contents of the two former break up into antherozoids, while the latter must be regarded as a

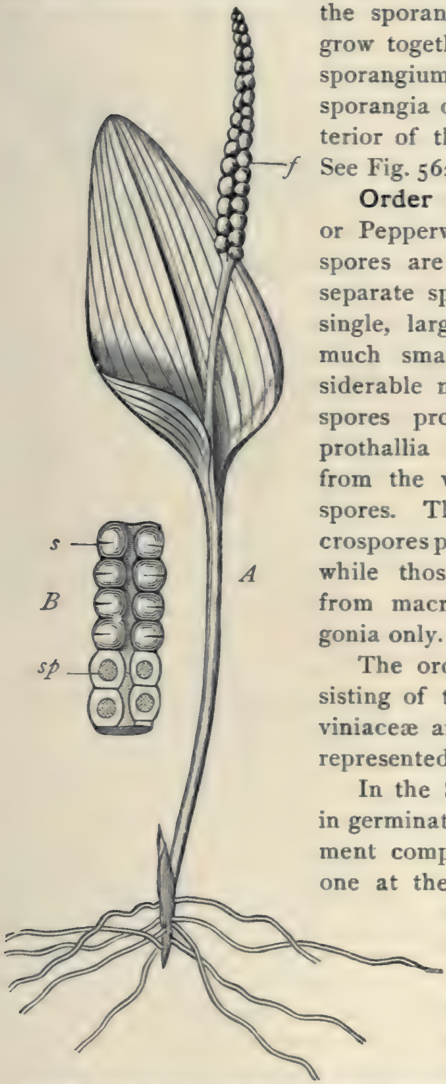

FIG. 562.—Ophioglossum vulgatum. *A*, entire plant; *f*, fruiting portion of leaf. *B*, part of fruiting portion of leaf, magnified. *s*, rounded portion of margin, containing in its interior a sporangial cavity, as shown below at *sp*, where a portion has been cut away so as to show the internal structure.

very rudimentary prothallium. The female prothallium is better developed, consisting of a mass of cells, but it projects but little from the spore. The plants are rootless, floating aquatics, having flat aerial leaves, and finely dissected, submerged ones. The sori are rounded bodies completely enclosed in an indusium, and borne near the base of the submerged leaves. See Fig. 563.

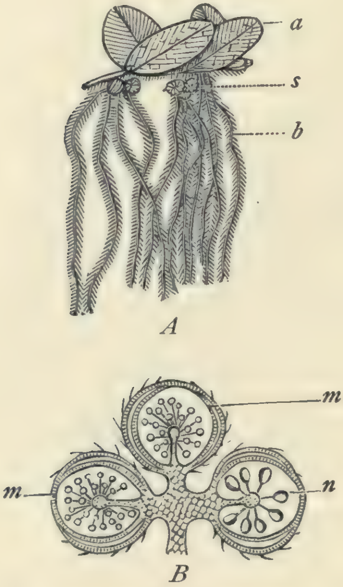

FIG. 563.

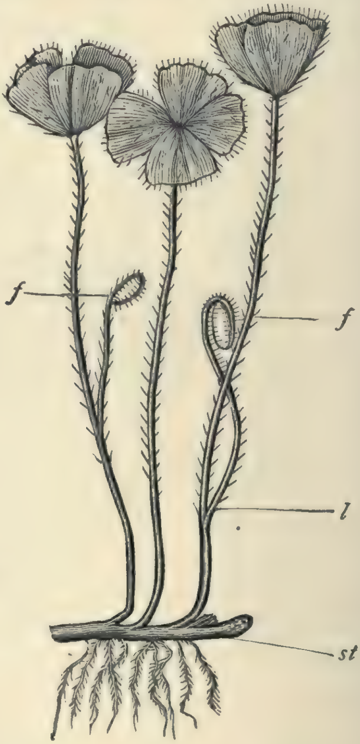

FIG. 564.

FIG. 563.—Salvinia natans. *A*, portion of plant showing aerial leaves, *a*, submerged leaves, *b*, and sori *s*, borne on the submerged leaves. *B*, a cluster of the sori in section, magnified about 10 diameters *n*, a sorus containing macrosporangia, and *m*, *m*, sori containing microsporangia. Partly after Sachs.

FIG. 564.—Marsilea salvatrix. *st*, stem, bearing roots and leaves; *l*, leaf petiole giving off a fructifying branch; *f*, *f*, fruits, containing sporangia which bear both macrospores and microspores.

In the Marsilias the contents of the microspore in germinating also form three cells, two of which together make up the antheridium, and the other, which is very small, stands for the prothallium; but they all remain enclosed within the spore until the antherozoids are ripe.

The female prothallium partly protudes as a hemispherical mass from the ruptured wall of the macrospore, but most of it remains concealed within the coats of the spore.

The fructification consists of a modified leaf-blade of pod-like appearance, which contains several sori, each enclosed in an indusium. In each sorus are sporangia which contain macrospores, and others which contain microspores. See Fig. 564. The Pilularias are closely related to Marsilia, and are classed in the same group. All the members of the order are aquatics.

CLASS III.—THE LYCOPODINEÆ, OR CLUB MOSS GROUP.

The plants of this class are, for the most part, small or moderate sized perennial herbs, sometimes with stems erect and rooting at the base, but more commonly creeping, with ascending or erect branches, which, in the majority of cases, originate dichotomously, though in some instances monopodially. With few exceptions, the stems and branches are thickly clothed with leaves. The latter, in the simplicity of their structure, are in strong contrast to those of the Ferns, being mostly of small size, without petioles or stipules, usually provided with but a single nerve, which constitutes a mid-vein, and the blade is never branching or compound.

The roots differ from those of most other plants, in being dichotomously branching. The sporangia are, in the majority of cases, borne on the leaves, but, in some instances, as in Psilotum and Selaginella, on the stem. The spore-bearing leaves may be of the ordinary form, or they may be somewhat modified in structure and crowded together, forming cones or spikes at the ends of some of the branches. Some members of the group bear but one kind of spores, others produce both macrospores and microspores.

There are three orders, the *Lycopodiaceæ*, the *Psilotaceæ* and the *Ligulatæ*.

Order A. The Lycopodiaceæ. All the existing forms of the group are isosporous, but the Lepidodendrons of the Coal Age, which must be regarded as belonging here, were heterosporous. The prothallia, which have been studied in only two species, are well-developed, subterranean, tuber-like bodies, which bear both antheridia and archegonia.

The ordinary or spore-bearing plants are all terrestrial, and moss-like in appearance, the stems being thickly clothed with small simple and often narrow leaves. Both stems and roots grow by an apical growth, not however from a single apical cell, but from a cluster of them. In habit, the stems may either be creeping, with erect or ascending branches, as in Lycopodium clavatum, or, less commonly, erect from the first, as in Lycopodium Selago. The stems nearly always appear to be forked, and in most cases are really so, but in a few instances the branching is actually monopodial.

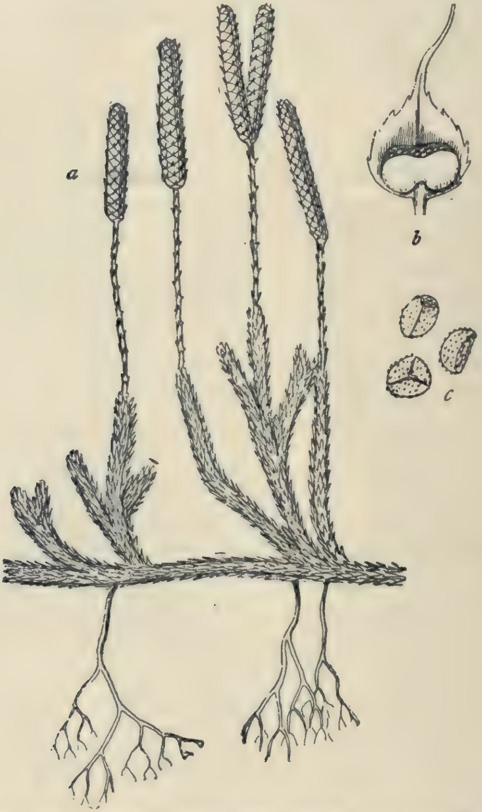

FIG. 565.—Fruiting branches of Lycopodium clavatum, about one-half natural size. *a*, fruiting cone: *b*, one of the scales of a cone showing inner surface, and one of the sporangia near its base, considerably magnified; *c*, three spores highly magnified.

The internal structure of the stems is somewhat peculiar. There is an axial fibro-vascular cylinder enclosed in a well-developed bundle-sheath, and the cylinder itself contains a number of fibro-vascular bundles which lie side by side, and are distinct from each other, or are united in various ways, but always in such a manner that an axial longitudinal section separates them into two symmetrical halves. The bundles, therefore, sometimes have the appearance of radial bundles. At the outer extremities of each of the bundles occur spiral tracheids of small diameter.

There are two genera, Lycopodium and Phylloglossum.

In the principal genus, *Lycopodium*, the sporangia, which are much larger than those of Ferns, occur singly on the upper surface of leaves near their base. In Lycopodium Selago and a few others, they are borne on ordinary leaves, and these not on any special part of the stem, but in most species they occur in terminal spikes composed of somewhat modified leaves. See Fig. 565.

Phylloglossum is a genus found only in Australia. The plants are of small size, and the stems bear a rosette of elongated leaves. The axis is continued into a slender stalk above, which bears a spike of small leaves in which the sporangia occur. The stems spring from a tuber, and the plants are multiplied vegetatively by means of adventitious shoots.

Order B. Psilotaceæ. This is a small group composed entirely of exotic shrubby plants of small size. They are distributed into two genera, one, the genus *Tmesipteris*, confined to Australia, and the other, *Psilotum*, occurring in the Sandwich Islands, the Molluccas and Madagascar as well. The *Psilotums* have erect, dichotomously branching, angular stems, with small, simple and distant leaves. They are entirely without true roots, peculiarly modified branches of the stem taking their place functionally.

The genus *Tmesipteris* has unbranching or sparingly branching stems, which have broader, better developed and more numerous leaves, but in most other respects resemble the Psilotums.

A distinctive peculiarity of the order consists in the way the sporangia are borne. They are sunken in the ends of very short lateral branches, and partially protected by two small leaves which rise on either side of them. The sporangia are in a cluster of from two to four, and bear but one kind of spores. See Fig. 566.

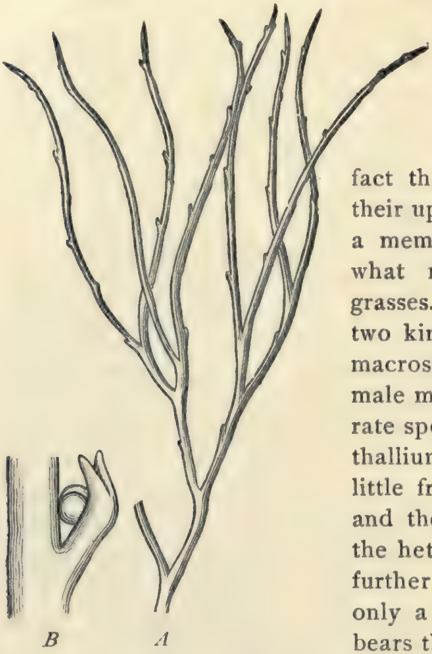

FIG. 566.—Psilotum triquetrum. *A*, part of plant, natural size. *B*, portion of stem, magnified, showing fructifying branch bearing at its apex two sporangia between two small leaves.

Order C. The Ligulatæ. The order is so named by reason of the fact that the leaves possess, on their upper surface near the base, a membranous appendage somewhat resembling the ligule of grasses. All the species produce two kinds of spores, large female macrospores and much smaller male microspores borne in separate sporangia. The female prothallium is small and projects but little from the coats of the spore, and the male prothallium, as in the heterosporus Filicineæ, is still further reduced, consisting of only a single minute cell which bears the antheridium.

There are two sub-orders, the *Selaginelleæ* and the *Isoeteæ.*

The *Selaginellas,* in general appearance, bear a considerable resemblance to the species of Lycopodium, but the dichotomous branching is in one plane and not in all planes ; the leaves are arranged in four vertical rows, and the members of opposite pairs are dissimilar in size or shape ; and the roots fork repeatedly, and the secondary branches decussate with the primary, the tertiary with the secondary, and so on. The sporangia are borne on the stem immediately above the insertion of the leaves so as to appear in their axils. The sporangia occur singly, and are of large size compared with those of Ferns ; the macrosporangia each contain four spores, while the microsporangia, which are ordinarily borne higher up on the axis, contain numerous small spores. Several species are common in cultivation as green-house plants; Selaginella apus, not an uncommon native species, grows in damp places, and might easily be mistaken for a Moss, and Selaginella rupestris, which has the aspect of a small Lycopodium, is common on rocks and in dry, sandy soil. Fig. 567 represents a portion of a fructifying stem of a Selaginella with a microsporangium and a macrosporangium enlarged.

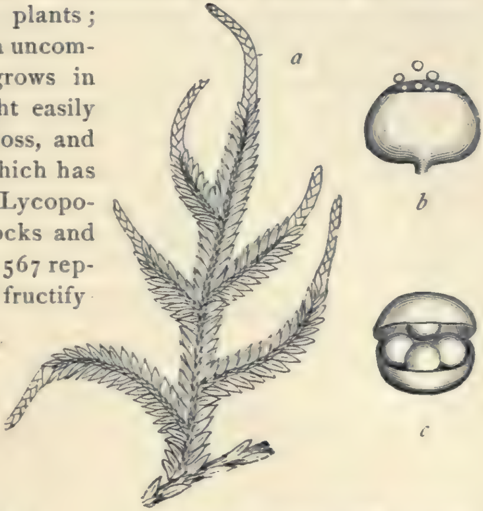

Fig. 567.—Fruiting branches of Selaginella, about natural size. *a*, spore-bearing portion; *b*, sporangium containing microspores, from the inner surface of one of the scales; *c*, sporangium from the inner surface of another scale, containing macrospores.

The *Isoetes*. In these species the stem is short, and the numerous leaves with which it is clothed are long and grass-like, and on the upper surface of the sheathing bases occurs a depression or pit in which the sporangia are borne, and just above this is the ligule. The macrosporangia contain numerous macrospores, and are borne by the outer leaves of the

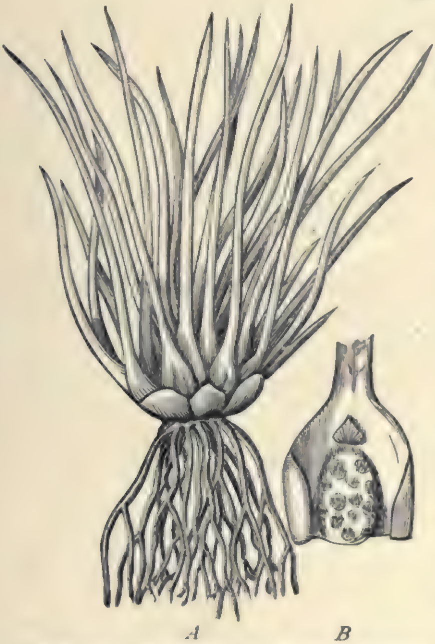

Fig. 568.—Isoëtes setacea. *A*, the entire plant. *B*, the base of one of the leaves, showing immature sporangium and, above it, the ligule.

fasicle, while the microsporangia are borne on the interior ones. Among the spores in both kinds of sporangia are borne cellular filaments or paraphyses. A few of the species are terrestrial or amphibious in their habits, but most are submerged aquatics, growing in water which does not contain much calcareous matter in solution. See Fig. 568.

CHAPTER XIV.

SERIES IV.—THE SPERMAPHYTA OR PHANEROGAMIA.

PRINCIPAL DIVISIONS.

- Gymnospermæ
  - Cycadeae.
  - Coniferæ.
  - Gnetaceæ.
- Angiospermæ
  - Monocotyledones
    - Helobiæ.
    - Glumifloræ.
    - Spadicifloræ or Nudifloræ.
    - Enantioblastæ.
    - Scitamineæ.
    - Gynandræ.
    - Liliifloræ.
  - Dicotyledones
    - Apetalæ
      - Julifloræ.
      - Centrospermæ.
    - Gamopetalæ.
      - Isocarpæ.
      - Anisocarpæ.
    - Choripetalæ.
      - Aphanocyclæ
      - Eucyclæ.
      - Tricoccæ.
      - Calycifloræ.

The Spermaphyta include the entire series of seed-bearing, as distinguished from spore-bearing, plants. The group contains the largest and most highly developed of all vegetable forms; by far the larger proportion of those plants we most admire for their beauty or desire for their usefulness. From them chiefly do we form our conceptions of vegetable life. They do more than any others, or all others combined, to give to the landscape its character and charm.

We have already obtained from our study of organography, which was mainly devoted to the organs of these plants, some idea of the immense variety of shapes, sizes and habits that occur among them. Some species, as the Wollfia, are mere green specks, barely distinctly visible to the naked eye, while others, as the giant Sequoia, attain the lofty height of more than four hundred and twenty feet. Some pass through the complete round of their life-history in a few days, while others outlive many generations of men; some have a soft, flabby structure, and are easily destroyed, while others are composed chiefly of hard and enduring tissues; some make their homes in the water, others in marshy places, others on dry ground, while still others prefer the arid wastes of the desert; some are parasitic or saprophytic, but the great majority are chlorophyll-bearing; some like the shade, others prefer the open sunshine; some flourish only on the borders of eternal snows, while others cannot thrive except in the perpetual warmth of the tropics; and there are indeed few corners of the earth so inhospitable as not to afford some of them a congenial abiding-place.

While it is probably true that, merely in the number of individuals, they are surpassed by some of the lower classes of Thallophyta, in the number of species they probably exceed all the other Series of plants put together.

The term *Spermaphyta* or Seed-plants, is appropriately applied to the members of the Series, because their most distinctive characteristic is the production of seeds. These, as we have already seen, are entirely different bodies from spores, being much more complex in their structure, containing within their seed-coats an embryo or plantlet which is usually so far developed as to possess the rudiments of stem, root and leaves. They often also contain an endosperm or perisperm, whose service is to nourish the growing embryo.

Since none of the lower plants produce seeds, there would seem, at first thought, to be a sharp line of separation between Seed-plants and all others, but such is not really the case. The process of seed-production is now known to be closely related to the sexual processes in the Pteridophyta, and the progress from the lowest forms of the latter group to the highest forms of Seed-plants, is one of easy gradations.

In both groups the reproductive organs are, with a few exceptions, borne upon the leaves; in the Seed-plants, however, particularly in the higher forms, these leaves, and often also others indirectly concerned in the reproductive process, are much more strongly modified and form a more or less conspicuous group, which we have already studied as the flower. Moreover, the ovules and pollen-sacs of seed-plants are homologous respectively with the macrosporangia and microsporangia of the higher Pteridophyta, and the embryo-sac in the ovule corresponds with the macrospore, and the pollen-grain with the microspore.

In the lower Pteridophyta, such as Ferns and Equisetums, we found that the prothallium or sexual generation attains a very considerable development, and continues some time as an independent plant, but in the higher members of the Series, as Salvinia, Isoëtes, etc., it becomes progressively of less and less importance, in some cases scarcely emerging from the coats of the spore. In Seed-plants the prothallium is still represented, but its degradation is carried a step farther. It consists of a few cells or a tissue formed in the embryo-sac, and it never bursts through the walls of the latter, but either remains as a part of the seed, or is afterwards absorbed by the forming embryo. The seed is, in fact, a macrospore which has, while still in contact with the parent plant and nourished by it, germinated and produced an internal prothallium, and a germ-cell or oösphere, which, after fertilization, has developed into an embryo, and only after these processes have been accomplished, has become free.

In like manner, the pollen-grains are microspores somewhat modified in accordance with the changes in the development of the macrospore. They are formed in the pollen-sac in the same way that microspores are in microsporangia, but the male prothallium which they produce in germinating, is, if possible, still more rudimentary or aborted altogether, and no motile antherozoids are produced. Instead, the entire pollen-grain, as we have found, is conveyed by the wind, by insects, or by some other agency either to the ovules direct, as in the Pines and their relatives, or to the stigma, which is a portion of a leaf or whorl of adnate leaves enclosing the ovules, as in the higher flowering-plants, and it there germinates and forms a pollen-tube which penetrates to the ovule, and through the micropyle of the latter to the surface of the embryo-sac, as was explained in Part I.

Compared with the preceding Series, the various organs of vegetation are more complex and better developed, the modifications of form and structure which organs of the same name assume

—the multiform adaptations of stems, leaves and roots, for example, to a variety of uses and changes of form to correspond with changed functions—is especially remarkable. While dichotomous branching is common in other groups of plants, in this it is the rare exception; roots, stems and leaves, if they branch at all, branch monopodially; the stems and roots do not grow by the division of a single apical cell, as is the case in all Pteridophyta, except the Lycopodineæ, but by a group of cells; and the fibro-vascular bundles of the stems and leaves are different in kind, being usually of the collateral variety.

By far the larger proportion of all Seed-plants are chlorophyll-bearing. Only a few have developed parasitic or saprophytic habits.

The Series is subdivided into two Classes, the GYMNOSPERMÆ or Seed-plants without ovaries, and the ANGIOSPERMÆ, or Seed-plants with ovaries.

THE GYMNOSPERMÆ.

The plants of this class are, without exception, woody-stemmed, terrestrial and chlorophyll-bearing forms, most of them attaining a considerable size, and some of them forming the largest of our forest trees. In the structure of their stems they show affinities with the highest forms of the Series, the Dicotyledons, since they possess a pith, medullary rays and a cambium zone; but their tissues are less complex, true wood-cells, and ducts being largely replaced by an intermediate tissue, the discigerous tracheids. In many other points they show themselves decidedly inferior to the rest of the Spermaphyta, and, in some important respects, closely allied to the Pteridophyta. The flowers, as a rule, are of very simple structure, consisting of leaves much less modified from the ordinary form than in most other flowering plants; they are never showy or nectar-bearing; the stamens and pistils are never found together in the same flower, but all the plants of the Class are either monœcious or diœcious; as implied in the word, *gymnospermæ*, the ovules are not enclosed in an ovary, but are borne on the base of an open carpel, or, more rarely, naked, on the end of a branch, and the cotyledons of the embryo are arranged in whorls, sometimes of two, but often of four, six, or some higher number.

Their alliance to the higher members of the preceding Series, is especially shown in the fact, that an endosperm, equivalent to the female prothallium of the heterosporous Ferns, is produced in the embryo-sac previous to fertilization, and bears archegonia in the same manner, and in the fact that the pollen-grains become two or more celled before emitting a pollen-tube, and at least one of the cells takes no part directly in the formation of the latter, but behaves like, and is really the equivalent of, the rudimentary male prothallium of Salvinia and Selaginalla.

The Class includes three orders, which, in appearance and habits of growth, differ widely from each other, but agree essentially in their modes of reproduction. They are the *Cycadeæ*, the *Coniferæ* and the *Gnetaceæ*.

(A) **The Cycadeæ.** The plants of this order have much the aspect of Tree-ferns with which, in fact, they are more strongly allied than are any other members of their class, having unbranching scaly stems crowned at their summit with ample pinnate leaves. They are slow-growing plants which, though once exceedingly abundant and playing an important part in the world's flora, are now rare, consisting of only about seventy-five species, and these confined to tropical and sub-tropical regions.

The stems, though externally scaly and unbranching, like those of Tree-ferns, more closely resemble in their internal structure those of the Pines and Dicotyledons, having the woody elements arranged in much the same way and growing in substantially the same manner. Compared with the Pines the medullary rays are broader, and the cells composing them thinner-walled and the pith is usually large. The woody elements consist of discigerous, scalariform or reticulate tracheids in the secondary wood, with a few spiral tracheids in the primary wood or medullary sheath, but true ducts are seldom found. The stems also differ from those of Ferns, in being continued downward into a tap-root.

The leaves are arranged on the stem in compact spirals, and consist of two kinds, the ample pinnate ones already mentioned, and more numerous, scale-like, brown, leathery, rudimentary ones. Every year or two the crown of foliage leaves is renewed by the unfolding of the large terminal bud.

The species are all diœcious, the male and female flowers being borne on different individuals. Both kinds are borne at the apex of the stem, the staminate ones consisting of leaves modified into shield-shaped scales compactly arranged on a short axis, in much the same way as in the spike-like fructification of Equisetum. Each scale bears on its under surface numerous pollen-sacs or microsporangia, which are usually collected into groups of from two to five each. See Fig. 569, *B*. The staminal leaves differ from those of most other flowering-plants, in becoming hard and woody, and persisting for a long time.

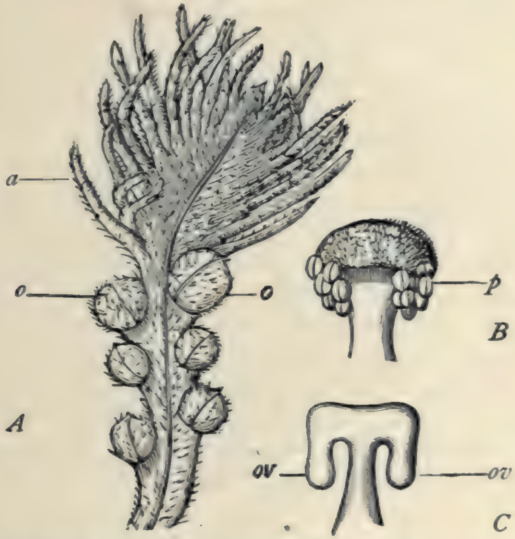

FIG. 569.—*A*, carpellary leaf of Cycas revoluta, about one-fourth natural size. *a*, one of the pinnæ of the leaf; *o*, *o*, ovules developed in the place of pinnæ. *B*, one of the anther-bearing scales from a staminate cone of Zamia, one of the Cycads; *p*, pollen-sacs. *C*, one of the carpellary scales from the fertile cone of Zamia, showing two ovules, *ov*, *ov*, pendent from the under surface.

The female flower is also, except in the genus Cycas, spike-like or cone-like in appearance, the cones often being of large size and made up of peltate scales, on the under surface of each of which two ovules or macrosporangia are borne. See Fig. 569, *C*. The ovules are orthotropous, and each consists of a nucellus enclosed in a single thick coat which, at maturity, becomes succulent. They are of large size, the largest in the vegetable kingdom, attaining, in some species, the size of a filbert before fertilization. The embryos are usually dicotyledonous, and the cotyledons do not escape from the seed-coats during germination.

The female flowers of the species of Cycas differ from those of other members of the order, in the fact that the ovule-bearing leaves form a rosette, composed of leaves similar in shape but smaller in size than the ordinary foliage ones, and the ovules take the place of the ordinary pinnæ. See Fig. 569, *A*. Moreover, the axis that bears the floral leaves does not stop growing, but is continued upward through the flower and bears above the latter both scale-like and ordinary leaves.

Cycas revoluta is commonly cultivated in hot-houses, and one species, Zamia integrifolia, commonly called the Coontie, is native to the United States, growing in southern Florida.

(B) **The Coniferæ** constitute by far the largest and most important order of the class. It includes the Pines, Yews, Cypresses, Firs, Larches, Junipers, Araucarias, etc. A few of the species are shrubs, but most are trees of medium or large size; the stems are very commonly excurrent or spire-shaped; branching occurs freely, and the branches spring from the leaf-axils, but not all, or even the larger proportion of the axils, produce buds; the leaves are, with few exceptions, unbranching, simple-veined and of small size, and are commonly very abundant, in some instances, as in the Arbor Vitæ and Red Cedar, so thickly clothing the branches that the branch itself is completely obscured. Many of the species produce, besides the foliage leaves, brown scales, which mainly serve a protective purpose, as bud-scales, etc., as in the Spruces; but in one Australian genus, Phyllocladus, no green leaves are developed, but leaf-like branches springing from the axils of scales, take their place.

In their internal structure and mode of growth, the stems very closely resemble those of Dicotyledons, the most important difference being the fact that the elements of the secondary wood consist almost entirely of discigerous trachieds. (See Vegetable Histology).

Nearly all the species produce terebinthinous secretions, and many valuable resinous and oleo-resinous products are obtained from the order.

The flowers are, in some species, monœcious, in others diœcious. The staminate flowers consist of shield-shaped scales compactly arranged along a lengthened axis, each scale bearing on its inferior surface two or more pollen-sacs. These often vary in number on the same plant. In the species of Spruce and Pine, there are two placed side by side on the staminal leaf, very much as in most of the higher flowering-plants ; in the common Juniper there are three roundish pollen-sacs ; in Taxus baccata (see Fig. 570, *C*) there are from three to eight, and in the Araucarias of the southern hemisphere, there are a large number of long cylindrical ones pendent from the lower surface of the shield-shaped scales. The staminal scales are nearly always smaller and of a different color from the ordinary

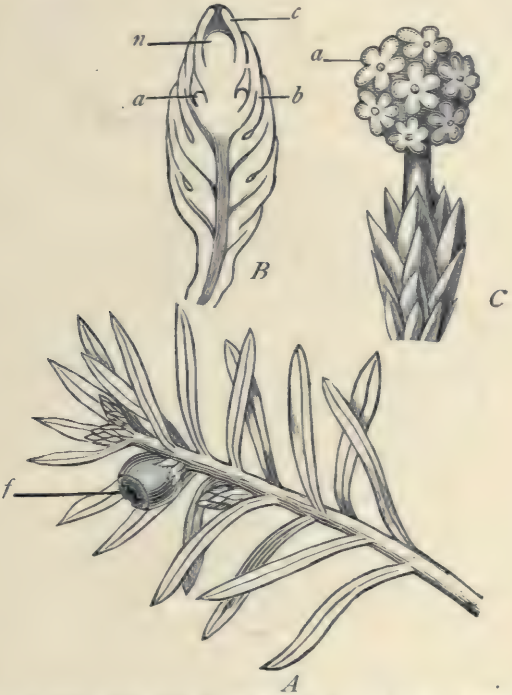

FIG. 570.—The Yew, Taxus baccata, showing flowers and fruit. *A*, branch, with ripe fruit, *f*, about natural size. *B*, longitudinal section of female flower, showing terminal ovule ; *n*, nucellus ; *c*, coat of ovule ; *a*, rudiment of aril, which later grows up and envelops the seed ; *b*, a bract. Magnified about 20 diameters. *C*, Male flower, showing terminal cone of staminate, shield-shaped scales, each with several pollen-sacs on the inferior surface ; *a*, one of the pollen-sacs. Magnified.

ones, but they are arranged in a similar manner on the stem. In this respect they show their inferiority to Angiosperms, for in the latter the differentiation between floral and ordinary leaves often extends to the phyllotaxy, the arrangement of the floral leaves frequently being quite different from that of the foliage leaves on the same plant.

The female flowers vary a good deal in the different species, particularly in the position of the ovules. In some, as the Yews, Fig. 570, *B*, the flower consists of a naked ovule borne at the apex of a short branch; in others, as the Spruces, Pines, Larches and Cedars, they form cones consisting of an axis, along which scales or bracts are compactly arranged in spiral order, and in the axil of each bract, and attached to it only at the base, occurs another, which bears on its upper surface two ovules, whose micropyles point downward (see Fig. 571, *A*); the Araucarias of the Southern hemisphere have flowers of similar structure, except that the carpellary scale is completely fused with the bract, in whose axil it is borne; in the Taxodiums, represented by the Bald Cypress of our Southern States, the fusion between carpellary scale and subtending bract, has also taken place, but the micropyle of the ovule is directed upward instead of downward; and in the Cupressineæ, to which belong the Juniper, Savin, Red Cedar and Arbor Vitæ, the carpellary scale is completely fused with the bract, the mycropyle of the ovule is directed upward, and the bracts are arranged on the axis in whorls instead of spirals. By some botanists the cone is regarded as an inflorescence or flower-cluster; by others as a single flower.

For illustrating more particularly the mode of reproduction in this group, we may take the Scotch Fir, *Pinus sylvestris*. This species is monœcious, and the staminate flowers are borne in clusters on the lower parts of shoots of the same season. Each scale produces two pollen-sacs placed longitudinally, side by side, on the lower surface. The pollen-grains when ripe consist of a central body with two vesicular, wing-like appendages, as is frequently the case with the pollen of Coniferæ. The body of the grain, or the pollen-grain proper, consists of two cells, a smaller vegetative one, representing a prothallium, and a larger one, which corresponds to that in the microspore of Selaginella, which produces antherozoids, but which here, in germinating, gives rise to a pollen-tube. The female flower is a cone borne at the apex of a small branch. Each fertile scale bears on either side of a central rib, near its base, two ovules, whose micropyles point obliquely downward. The ovule-bearing scale is in the axil of a bract, and slightly attached to it at the base. Each ovule consists of a nucellus enclosed in a single coat, as is most commonly the case in Gymnosperms. When the ripened pollen-sacs begin to open to shed their pollen, the axis of the fertile cone lengthens so as to separate the scales and permit the access of the pollen. The latter, conveyed by the wind and falling upon the ovule-bearing scale, slips down it to the base, being guided in its course partly by the projecting mid-rib, partly by the peculiar formation of the scale, and partly by the appendages of the pollen-grains, until they rest in the micropyles of the ovules. The pollination thus accomplished, the scales of the cone close together at the top, and become agglutinated with resinous matter. At the time this takes place the ovule is very

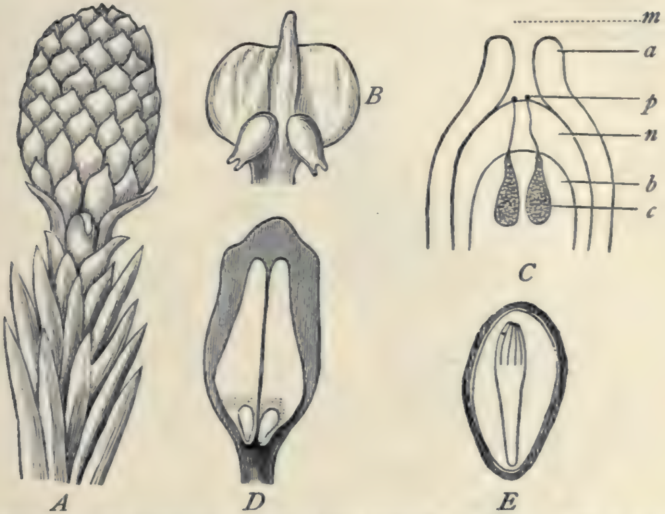

FIG. 571. – **Pinus sylvestris.** *A*, female cone somewhat enlarged ; *B*, one of the fruiting scales considerably magnified, showing upper surface and two ovules near its base, pointing obliquely downward. The bract, in the axil of which the fruiting-scale is borne, is concealed behind the latter. *C*, diagram of upper part of ovule much magnified ; *a*, coat of ovule ; *m*, micropyle ; *p*, pollen-grain sending tube into nucellus, *n* ; *b*, embryo-sac filled with endosperm : *c*, one of the two archegonia. *D*, scale with ripened seeds ; these each possess a prominent wing. *E*, seed with wing removed and cut longitudinally to show albumen and embryo.

imperfectly developed, and in this species the process of fertilization occupies a long time, not being completed, in fact, until the succeeding year.

When the ovule is fully matured and ready to receive the fertilizing influence of the pollen-tube, a large embryo-sac has been formed in the nucellus, and this has been filled with cells constituting a prothallium, and in this are formed one or more archegonia, which structurally resemble the corresponding organs of the Pteridophytes, possessing a *body*, which contains a germ-cell or oösphere, and a *neck* composed of rows of small cells. The pollen-tube, formed from the germinating pollen-grain, penetrates the tissues of the nucellus and grows down through them to the neck of the archegonium, and its protoplasm mingles with that of the oösphere. In some species the nucleus of the one has been observed to blend with that of the other. The fertilized oösphere then begins to develop in its interior an elongated and commonly more or less contorted mass of cells, called the

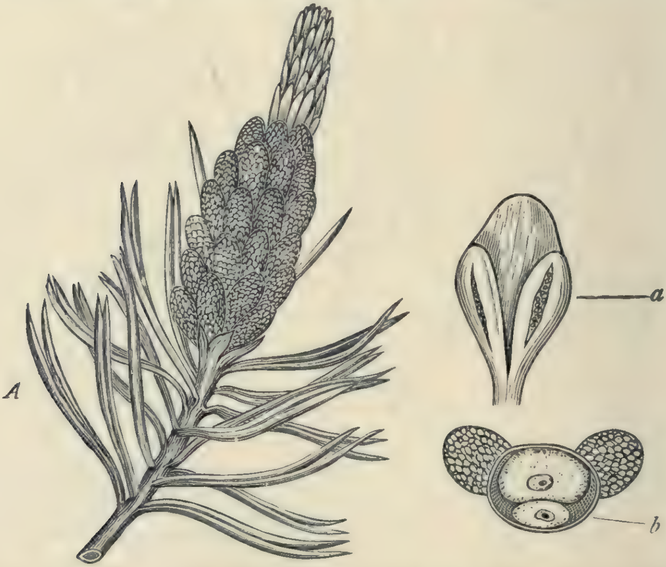

FIG. 572.—Pinus sylvestris. *A*, branch, showing cluster of staminate cones near its apex ; *a*, one of the staminal leaves magnified, showing two pollen-sacs ; *b*, a pollen-grain highly magnified, showing outer coat with two cellular, wing-like appendages. The body of the grain contains two cells, one large and one small one.

suspensor. This usually pushes its way downward through the wall of the oöspore into the cellular tissues of the embryo-sac, and at its lower end forms a mass of cells from which the embryo is developed. The time of pollination to the ripening of the seed, comprises, in this and many other species of the Coniferæ, two entire seasons. The seed is albuminous, and the embryo, as in many other species of Abietinæ and in some other Coniferæ, is polycotyledonous. The reproduction of Pinus sylvestris is illustrated in Figs. 571 and 572.

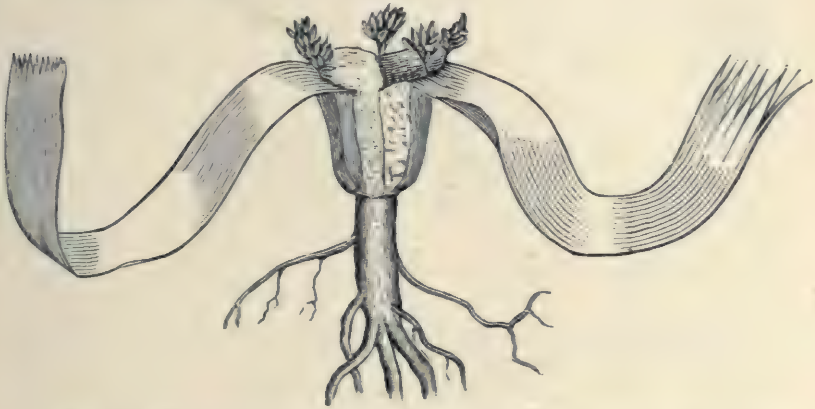

FIG. 573.—Welwitschia mirabilis, entire plant, about one-thirtieth natural size. After Hooker.

(C) **The Gnetaceæ,** or Joint-Firs, constitute a small but diversified order of plants, consisting of undershrubs, shrubs, and small or moderate-sized trees. There are only about forty species in all, and these are distributed into the three genera, *Ephedra*, *Gnetum* and *Welwitschia*. The *Ephedras* are shrubs or undershrubs with much the aspect of Equisetums, having slender, cylindrical, jointed branches covered with a green rind, and bearing at the joints a pair of opposite small leaves, which are connate at the base, forming a two-toothed sheath.

The *Gnetums* also have opposite leaves, but these are large, broadly lanceolate or oval, entire, and pinnately veined. The remarkable genus, Welwitschia, is represented by but one species, Welwitschia mirabilis, a native of South Africa. It has a short, thick stem, which rises but a few inches above the soil, and is continued downward into a long tap-root. From opposite sides, just below the summit of the stem, arise two long, strap-shaped persistent foliage leaves, several feet long, and usually more or less fringed and torn at the apex, the only leaves the plant possesses, and from the circumference of the broad apex of the stem, just above these, spring the branches of the cymose inflorescence. These arise from the axils of bracts, and are jointed and dichotomously branching. See Fig. 573.

The flowers in some species of the Gnetaceæ are monœcious, in others diœcious, and both male and female flowers are invested and protected by modified leaves, forming a kind of perianth somewhat similar in character to that of the higher flowering-plants. Each stamen bears either two or four pollen-sacs, the ovules, like those of the higher plants, have two coats, and the embryos are dicotyledonous.

The members of the order, unlike the Coniferæ, are destitute of resinous secretions.

CHAPTER XV.—THE SPERMAPHYTA (CONTINUED).

CLASS II.—THE ANGIOSPERMÆ.

The plants of this class greatly excel the preceding, and in fact all others, in the number of their species, and in the variety of their habits. There are probably not less than one hundred thousand species, all told. They include the great majority of our forest trees, and nearly all our shrubs, herbs, marsh plants and flowering aquatics. A few among them have acquired parasitic or saprophytic habits, and are destitute of chlorophyll, but these are the rare exceptions; by far the larger part are chlorophyll-bearing.

Their tissues are, on the whole, more complex than those of Gymnosperms, and their vegetative organs, particularly the leaves, are better developed. Their superiority is shown most conspicuously, however, in the structure of their flowers. The reproductive organs—pollen-grains and ovules—are, as a rule, borne on leaves, or rarely the ovules occur at the end of the axis, which is also true of some Gymnosperms; but in Angiosperms, usually, the floral branch and its leaves, both those which directly bear the pollen grains and ovules, and others, called the perianth, exterior to them, are much more strongly modified or highly specialized, forming a flower which is more or less conspicuously different from the rest of the plant, and frequently very beautiful in form and coloring. The perianth is usually differentiated into calyx and corolla, each of which, as we have seen in Part I, performs indirectly more or less important service in the reproductive process. The part of the axis on which the floral leaves are borne, is usually very short, and the leaves themselves compactly arranged in whorls or spirals. Moreover, the axis nearly ceases its growth after these leaves are formed, and does not, except in occasional monstrosities, produce buds in their axils. The short, often expanded part of the axis, called the receptacle, that bears the floral leaves, is frequently prolonged below into a stalk or peduncle, which may either be naked or bear small modified leaves, the bracteoles. In all Gymnosperms, as we have seen, the flowers are either monœcious or diœcious; but while this is the case also with many Angiosperms, the majority are hermaphrodite, or produce both stamens and pistils together in the same flower, the carpellary leaves occupying the centre of the flower, while the stamens are borne immediately below or exterior to them. But perhaps the most conspicuous difference between the two Classes, is the fact that, in Angiosperms, the ovules are enclosed, while in Gymnosperms they are naked or unenclosed. The vessel which, in the former class, contains the ovules, is, as we have already learned, either a single carpellary leaf or a whorl of two or more of them, which have become adnate.

Other differences, though less conspicuous and less easily detected, but of still greater significance, as showing the relations between the two groups, and the connection of both with the Pteridophyta, are found in the pollen-grains and embryo-sacs. The pollen-grain of the Gymnosperms we found to be a microspore, which develops a very rudimentary prothallium, consisting of a very small cell, and another cell, which, instead of producing antherozoids, gives origin to a pollen-tube. Now, in Angiosperms, also, the pollen-grain, before it is quite ripe, develops, in some cases, two cells in its interior, one with a curved, vermiform nucleus, the other with an elliptical one; but the two cells do not usually become enclosed in cellulose walls; and when the pollen-tube is formed, the only indication of their former existence that remains, is the presence of the two nuclei still to be seen within it. Only one of these, however, the worm-shaped one, appears to take part in fertilization; the other is the vegetative one, and undoubtedly represents the prothallium. See Fig. 574.

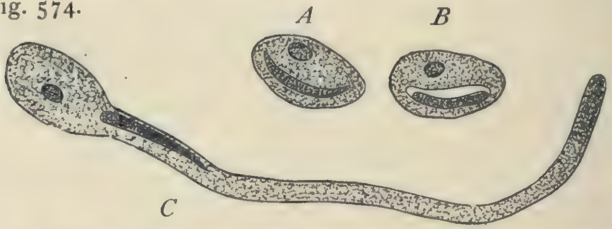

FIG. 574.—Pollen of Tradescantia Virginica. *A*, showing small vegetative and larger vermiform generative nucleus. In *B*, it will be seen that the generative nucleus belongs to a distinct cell, which is smaller in size than the vegetative cell. *C*, shows the pollen-grain germinating, and the generative nucleus passing down into the tube. The Figures after Coulter and Rose.

The female prothallium, formed in the embryo-sac of Angiosperms, is much more rudimentary than in Gymnosperms, being represented only by the three cells developed in the base of the embryo-sac, called the antipodal cells. (See Fig. 296, p. 100). It may be that the three cells, constituting the egg-apparatus, correspond to the archegonium of Gymnosperms, but this point is yet unsettled. It is only after fertilization is effected that an endosperm is developed in this group of plants. It serves the same purpose as the endosperm formed in the embryo-sac of Gymnosperms previous to fertilization, and is called by the same name. It is obviously, however, not the same organ, but is rather to be regarded as a new formation.

The Class includes two markedly distinct sub-classes, the *Monocotyledons* and the *Dicotyledons*.

THE MONOCOTYLEDONS.

Plants of this sub-class seldom show in their stems any distinction between wood and bark; they are without medullary rays; their fibro-vascular bundles, which are of the closed collateral variety, are not arranged radially about a central pith, as are the bundles in the stems of Gymnosperms and Dicotyledons, and there is usually no cambium zone by which the stems increase in thickness. (See Vegetable Histology).

The primary root, though present in the embryo, in most cases soon ceases to grow, and nutriment is absorbed from the soil, chiefly from adventitious roots, which spring laterally from the stem. Moreover, these roots possess no cambium zone, have no medullary rays, and undergo no important secondary changes as do the roots of Dicotyledons, and the central radial bundle commonly has more numerous xylem and phloëm rays, and the endodermis which encloses it, is usually composed of thick-walled cells.

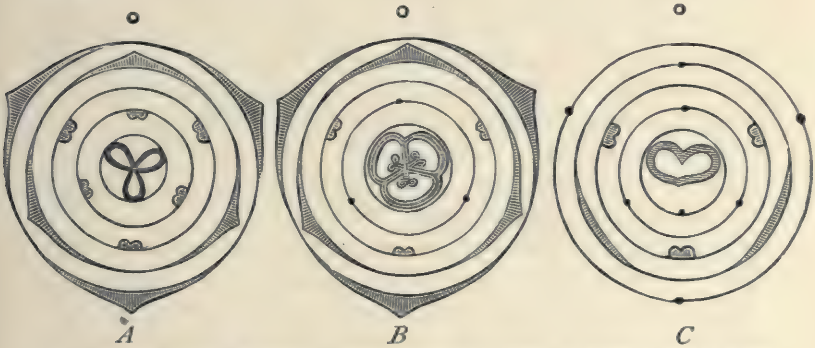

FIG. 575.—Floral diagrams of flowers of Monocotyledons. *A*, typical flower of Monocotyledon; *B*, diagram of flower of Iris, with the inner staminal whorl aborted; *C*, diagram of flower of a Grass with the outer perianth and inner staminal whorls completely aborted, and one piece each of the inner whorl of the perianth, and of the whorl of pistils, aborted.

The leaves, except those of the Arums, Yams and Smilaxes, are seldom reticulate, but are mostly parallel-veined or nerved, and the weaker veins are deeply buried in the mesophyll, and do not stand out so prominently on the lower surface as do those of Dicotyledons; they are not often opposite or whorled, but usually arranged on one of the simpler of the alternate plans, as one-half, one-third, one-fourth, though occasionally in a more complex manner; they are less commonly provided with stipules than the leaves of Dicotyledons; they are not usually articulated to the stem, and the blades seldom branch into compound forms.

The flowers are most commonly constructed on the numerical plan of three, and normally consist of five alternating whorls, one of sepals, one of petals, two of stamens and one of pistils. See Fig. 575, *A*. But there are numerous cases where one or more entire whorls, or parts of some of them, have become aborted, and in some instances, on the other hand, the number is multiplied beyond the normal. In the Grasses, the outer whorl of the perianth is entirely wanting, and the inner is usually only partially represented by two small scales, one whorl of stamens is usually absent, and frequently but one or two of the carpellary leaves is present. See Diagram, Fig. 575, *C*.

In the Flowering-rush (Butomus), on the other hand, all the whorls are present, the outer staminal one contains six instead of three stamens, and there are two whorls of three carpellary leaves each, composing the gynæcium. See Fig. 576. In the majority of cases, the perianth whorls, when present, are similar in color, as in the Tulip and Iris, but sometimes the calyx is green and the corolla colored, as in Trillium and Tradescantia.

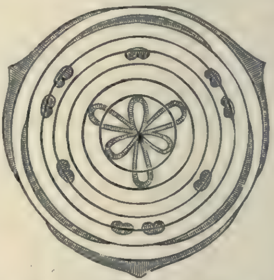

FIG. 576.—Diagram of flower of Butomus, or Flowering-rush, showing a doubling in the outer whorl of stamens, and two whorls, instead of one, of pistils.

The seeds, in most cases, possess a copious endosperm, with a relatively small embryo, but in some species, as most Orchidaceæ, no endosperm is formed at all; and in the Alismaceæ, Naiadaceæ and Juncagineæ, it is formed, but very soon disappears; and in the Scitamineæ a copious perisperm is developed in its stead.

But perhaps the most distinctive characteristic of the group lies in the structure of the embryo. This is monocotyledonous; that is, instead of an opposite pair of cotyledons, as in many Gymnosperms, and nearly all Dicotyledons, only one embryonic leaf occurs on the first node; if others are present, they alternate with it, and are enfolded by it. As this is the only conspicuous one, it is called the cotyledon. The embryo is usually straight and cylindrical or obconical, from the thickening of the cotyledon toward its upper end, but in a few cases, as in Potomogeton, it is elongated and coiled. The axial part (caulicle and radicle) is usually very short and nearly enclosed in the relatively large cotyledon, but in Sagittaria, Vallisneria, Hydrocharis, and their relatives, the axis is more conspicuous than the cotyledon. When the seed germinates, in some cases the radicle scarcely grows at all, but is almost immediately displaced functionally by adventitious roots which spring from above it, as in the Grasses; but in most cases it grows vigorously for a short time and then stops, giving way to adventitious roots.

The sub-class includes about fifty natural orders, and upwards of eighteen thousand species, which are distributed into seven sub-divisions, as follows:

Division A.—*The Helobiæ.*
Division B.—*The Glumifloræ.*
Division C.—*The Spadicifloræ or Nudifloræ.*
Division D.—*The Enantioblastæ.*
Division E.—*The Scitamineæ.*
Division F.—*The Gynandræ, and*
Division G.—*Liliifloræ.*

(A) **The Helobiæ** are all marsh or water plants, some with more and others with fewer than the typical number of floral whorls. The latter are always symmetrically arranged, the carpels always three or more and distinct, and the seeds contain little or no endosperm. To this group belong the Frog-bits, Vallisnerias, Water-Plantains and Triglochins.

(B) **The Glumifloræ** are either destitute of a perianth, or have a very rudimentary one, and not infrequently the stamens and pistils are reduced in number; the flowers are enclosed in scaly or glumaceous bracts, and they are usually arranged in spikes or panicles. To this group belong the Grasses and Sedges.

(C) **The Spadicifloræ** or **Nudifloræ,** as they are also called, bear clusters of small, numerous, usually diclinous flowers, having an inconspicuous perianth, or sometimes none at all. The clusters are either a spadix, a head, or a panicle with fleshy branches, and are nearly always enveloped in a spathe. Both staminate and pistillate flowers are usually borne in the same inflorescence, the ovaries are always superior, the embryo is small, and, except in the Duckweeds and Naiads, the albumen is copious. The Arums, Screw-pines, Palms and Cat-tails, are other members of the group.

(D) **The Enantioblastæ** are either succulent herbs or grass-like plants. The flowers are in cymose clusters; the floral leaves usually consist of five whorls of three each, but sometimes the flowers are dimerous; the perianth whorls are, in some species, showy and differentiated into calyx and corolla, in others they are glumaceous; the pistils are superior, syncarpous, and two or three celled, and the seeds are orthotropous and albuminous. The Restias, Pipeworts, Xyrids, and Spiderworts, are the chief representatives of the group.

(E) **The Scitamineæ** have unsymmetrical flowers with a two-whorled perianth, which, in most species, is petaloid, but in some is differentiated into calyx and corolla; some of the stamens are frequently aborted, or are represented only by stamen-like bodies or staminodes; the pistil is syncarpous, and the ovary is three-celled and inferior; the fruit is either a berry or a capsule; and the seeds are destitute of an endosperm, but have a copiously developed perisperm. The plants are large herbs, mostly perennial, and have ample, pinni-nerved leaves. To this group belong the Bananas, Gingers and Cannas.

(F) **The Gynandræ** are characterized by their asymmetrical trimerous flowers; their two-whorled, petaloid perianths; their gynandrous stamens, which, by abortion, fall below the normal number; their pollen, which is commonly either in clusters of four grains each, or aggregated into larger masses, called pollinia; their ovaries, which are inferior and composed of three united carpels; their numerous, very minute seeds, which are without an endosperm, and their very imperfectly developed embryos which are not differentiated into rudimentary root, stem and leaf. To this group belong the Orchids and the closely allied Apostasias.

(G) **The Liliifloræ** constitute a large group which present considerable diversity in the different orders, some having an indeterminate and others a determinate anthotaxy ; some flowers having a large, showy perianth, others, an inconspicuous or even a glumaceous one ; some with symmetrical, others with asymmetrical flowers, and some with a superior, others with inferior ovaries. Moreover, they differ among themselves considerably in habit, some being woody, others herbaceous ; some having an erect, others a trailing or climbing habit, and a few, as the Yuccas and Dracænas, have large woody trunks, which increase in thickness by means of a meristem area in the cortex. See Fig. 449. The great majority produce narrow or grass-like, parallel-nerved leaves, but a few, as the Smilaxes and Yams, bear broad, reticulate ones. They agree with each other, however, in their two-whorled perianths, their trilocular ovaries and their albuminous seeds. The group includes the Lilies, Amaryllises, Dracænas, Yuccas, Smilaxes, Yams, Bloodworts, Bromelias, Irises, Pickerel-weeds and Taccas.

The Monocotyledons include many species which are highly prized for their usefulness, as well as many others which are valued for ornament. The Grasses, containing as they do, the cereals, Wheat, Rye, Barley, Rice, Oats and Maize, and sugar-producing plants, such as the Sugar-cane and Sorghum, besides many valuable pasture plants, must take first rank among all the families of plants for their utility. The Palms are highly useful to the tropical races of mankind, furnishing them with food, building materials, cordage, sugar, and, in fact, in some cases, with nearly all the necessaries of life. Among the most useful species are the Date, Cocoanut, Sago, Bastard Sago, Palmyra and Areca-nut Palms. The Bananas and Cannas are also important food-producing plants, and some of the Yams and Lilies also afford valuable food products.

The Lilies yield such important medicines as Aloes, Squill, Garlic, Veratrum viride, Cevadilla and Colchicum ; from the Smilaxes we obtain Sarsaparilla ; from the Irises, Orris-root, Blue-flag and Saffron ; from the Cannas, Arrowroot ; from the Gingers, common Ginger-root, Curcuma, Galangal, Cardamom fruits, and Grains of Paradise ; from the Orchids, Salep, Vanilla and Cypripedium ; and from the Arums, Indian Turnip, Calamus and some other drugs of less importance.

Among those cultivated and admired for their beauty are the

Richardias and Calladiums belonging to the Arum family; the Lily of the Valley, Day Lilies, Tulips, Hyacinths, Tuberoses, Tritomas and many others belonging to the Lily family; the Irises, Crocuses, and Gladioluses belonging to the Iris family; the Snowdrops, Daffodils, Jonquils and Amaryllis belonging to the Amaryllis family; and the Cypripediums, Oncidiums, Epidendrums, Catasetums, Vandas and many other interesting plants belonging to the Orchis family.

CHAPTER XVI.—The Spermaphyta.

THE ANGIOSPERMÆ (Continued).

The Dicotyledons.

The stems of Dicotyledons, like those of Gymnosperms, have the collateral fibro-vascular bundles arranged radially about a pith, and separated from each other by medullary rays, and in nearly all cases secondary thickening takes place by means of a cambium zone which lies between the wood and bark, but their tissues are more complex, particularly those of the secondary wood, which usually consist of wood-cells, wood parenchyma, tracheids and ducts of various kinds, and frequently also of some other tissues. The branching is always monopodial, and nearly always from axillary buds.

The primary root is often strongly developed, and with its branches constitutes the principal root-system of the plant, but adventitious roots are also common, and in some instances early replace functionally the primary roots, as they do in Monocotyledons. The roots in most cases undergo important secondary changes, increasing in thickness by means of a cambium zone and developing medullary rays resembling those of the stem. The primary radial fibro-vascular bundle is usually few-rayed, and the walls of the endodermal cells which enclose it are seldom thickened. (See Vegetable Histology).

The leaves are remarkable for the variety of their forms and modifications; they may be opposite, whorled or alternate, and in many cases the phyllotaxy is quite complex; they are frequently stipulate, often toothed, incised, or branched into compound forms; with very few exceptions, their venation is reticulate, and the veins, except in succulent forms, are prominent on the lower surface. They are most commonly petiolate, seldom sheathing or clasping, and, in most instances, are articulated to the stem.

The flowers present very great diversity both of form and arrangement. In the majority of cases the floral organs consist of four alternate whorls, one of sepals, one of petals, one of stamens and one of pistils. See Fig. 577, *A*. The prevailing numerical plan is that of five, but not uncommonly the parts are in fours (see Fig. 577, *C*), less frequently they are in twos, threes or sixes. There are, however, numerous deviations from the type, due either to the suppression of some of the whorls or a part of them, or to the abnormal multiplication of some of them. The corolla, particularly, is liable to be wanting, and the stamens are especially liable to consist of multiple whorls. In the Magnoliaceæ, the Ranuculaceæ, the leafy Calycanthaceæ and the Nympheaceæ, some or all of the floral organs may be arranged in spirals rather than whorls.

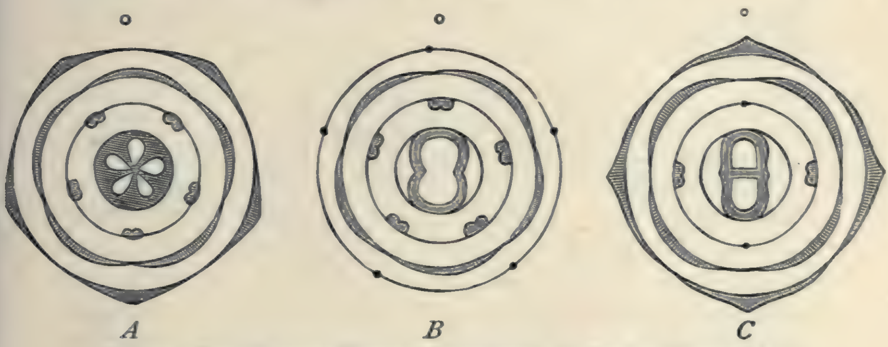

FIG. 577.—Floral diagrams of flowers of Dicotyledons. *A*, diagram of flower of Aralia, consisting of four whorls of five alternating parts each; *B*, diagram of flower of Compositæ, calyx wanting (or only represented in the pappus), the pistil consisting of two coalesced carpels and five each of the petals and stamens; *C*, diagram of tetramerous flower of Oleaceæ, two stamens and two carpels wanting.

When both whorls of the perianth are present, they are seldom alike, but are differentiated into calyx and corolla. Irregular and asymmetrical flowers are more common in Dicotyledons than in Monocotyledons, the stamens, like the ordinary leaves are more liable to branch, and the carpels are more likely to deviate from the numerical plan of the flower.

The embryos of Dicotyledons are also relatively large and well developed. They may be associated in the seed with a copious endosperm, as in the Spurges, Umbelworts and Polygonums, or with one which is relatively small in quantity, as in the Mints and Milkweeds, or the endosperm may be completely absorbed before the seed is ripe, as in the Oaks, Cucumbers, Roses and Cresses. In nearly every case it is formed copiously at first, and usually by internal cell-formation within the embryo-sac; it may or may not be completely absorbed before the seed is ripe. It is rarely the case that the embryo is very rudimentary in the ripe seed, except in chlorophylless parasites and saprophytes, such as Monotropa and the Orobanchaceæ, where it often consists of a cluster of only a few cells. In the seeds of other species, cotyledons, caulicle, radicle and plumule, are usually distinguishable. The plumule, though, is sometimes wanting, even in embryos otherwise well developed, being represented only by the naked apex of the caulicle rising between the bases of the cotyledons, as in the species of Cucurbita. The embryos, in nearly all cases, are strictly dicotyledonous, but, in a few instances, as already explained in Part I, they become falsely monocotyledonous or falsely acotyledonous by the abortion of one or both of the cotyledons, and it rarely happens, on the other hand, that a plant which ordinarily produces a dicotyledonous embryo, develops one with three. This has been known to occur in the Oak and Almond.

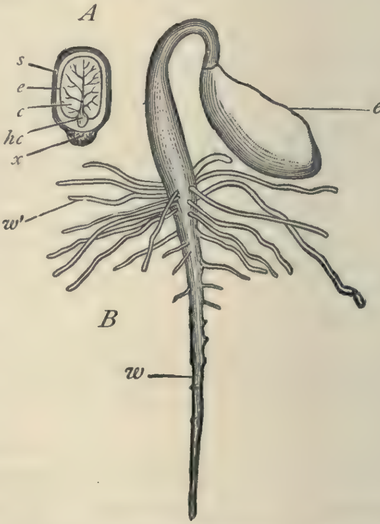

FIG. 578.—Ricinus communis. *A*, ripe seed laid open longitudinally; *s*, testa; *e*, endosperm; *c*, cotyledon; *hc*, hypocotyledonary part of caulicle; *x*, strophiole or caruncle. *B*, germinating seed with the cotyledons still buried in the endosperm, *e*; *w*, primary root; w' secondary roots. After Sachs.

In germination, also, the embryo behaves differently from that of Monocotyledons, in the relatively strong growth which the primary root or radicle always makes. It pushes out of the seed-coats and attains a considerable size, even while the rest of the embryo is still contained within the seed. See Fig. 578. The cotyledons may either remain enclosed within the seed-coats and wither, after the nutriment in them has been exhausted, or they may be carried above-ground, performing for a time the functions of foliage leaves.

To the Dicotyledons belong all the trees, except the Pines and their congeners, and nearly all the shrubby plants and a large portion of the herbs that constitute the native flora of the northern United States. They form by far the largest group of flowering plants, much larger, in fact, than all the others combined. About two hundred natural orders, including upwards of eighty thousand species, are recognized by botanists.

They are divided into three principal divisions, as follows:

Division A.—*The Apetalæ.*
Division B.—*The Gamopetalæ.*
Division C.—*The Choripetalæ.*

(A) **The Apetalæ** have usually small and inconspicuous flowers, which are mostly destitute of a corolla, and frequently also of a calyx. There are two subdivisions, the *Juliflorœ* and the *Centrospermœ.*

The *Juliflorœ* have their small flowers usually arranged in spikes, catkins, heads, or sometimes panicles; the flowers are mostly separated, the staminate and pistillate occurring in distinct clusters, sometimes both on the same plants, sometimes on different plants. The group is represented by the *Amentaceœ,* including the Birches, Oaks, Walnuts, Hazels, Sweet-gales, Willows and Casuarinas; the *Piperineœ,* including the Peppers, Lizard-tails and Chloranths, and the *Urticineœ,* including the Nettles, Elms, Hackberries, Bread-fruits, Figs, Mulberries, Sycamores and Hemps.

The *Centrospermœ* usually have hermaphrodite flowers, with a one, or rarely two, whorled perianth, frequently twice as many stamens as sepals, and superior, usually one-celled ovaries, which either produce a single, basilar campylotropous ovule or a central placenta, bearing numerous ovules. The group includes the

Buckwheats, Four-o'clocks, Chenopods, Amaranths, Pokeweeds, Portulaccas and Pinks.

With the Apetalæ are also usually classed a few other forms of doubtful affinity, including the Birthworts, Loranths or Mistletoes, Sandalwoods, Hornworts, Podostemads, and Balanophoras.

(B) **The Gamopetalæ** are distinguished from the other divisions of the sub-class by the fact that the calyx and corolla are usually both represented and the parts of the latter are more or less united.

They are subdivided into the *Isocarpæ* and the *Anisocarpæ*. The former are characterized by having as many carpels as sepals and petals; the carpels are united with each other to form a compound pistil which is usually superior, and the stamens are often in two or more whorls. The latter have but two or three carpels, always fewer than the sepals or petals, united into a compound pistil. The staminal whorls are never increased beyond the normal number. To the *Isocarpæ* belong the *Ericaceæ*, including the Heaths, Epacrids, Rhododendrons, Pyrolas, Monotropas, and Whortleberries; the *Primulineæ*, including the Primroses, Leadworts, and Myrsinias; and the *Dyospyrineæ*, including the Star-apples, Ebonies and Storaxes. To the *Anisocarpæ* belong the *Tubulifloræ*, including the Nightshades, Morning-glories, Phloxes, Borrages, and Hydrophylls; the *Contortæ*, including the Jasmines, Olives, Loganias, Dogbanes, Milkweeds and Gentians; the *Labiatifloræ*, including the Mints, Scrophularias, Verbenas, Plantains, Broom-ropes, Bladderworts, Bignonias, Gesneras, Acanthuses and a few other, mostly tropical forms; the *Aggregatæ*, including the Honeysuckles, Madders, Valerians, Composites, Teasels and Calyceras, and the *Campanulineæ*, including the Campanulas or Bellworts, Lobelias, Cucurbits, Gardenias and Stylidias.

(C) **The Choripetalæ** include plants whose flowers are usually provided with both calyx and corolla, and the latter is composed of distinct petals. There are four subdivisions, the *Aphanocyclæ*, the *Eucyclæ*, the *Tricoccæ* and the *Calycifloræ*.

In the *Aphanocyclæ*, the perianth is usually double, the stamens are mostly more numerous than the leaves of the calyx or corolla, and are frequently arranged in spirals rather than in whorls, and the pistils are usually superior and commonly distinct from each other, or but partially united. Under this are the *Polycarpicæ*, represented by the Crowfoots, Dillenias, Custard Apples, Magnolias, Schizandras, Calycanthuses, Barberries, Moonseeds, Laurels and Nutmegs; the *Hydropeltideæ*, including the Nelumbiums, Brasenias and Water-lilies; the *Crucifloræ*, including the Poppies, Fumitories, Cresses and Capers; the *Cistifloræ*, including the Mignonettes, Sundews, Violets, Side-saddle Flowers, Pitcher-leaves, Rock-roses, Hypericums, Bixineæ, Frankenias, Tamarisks, Camellias, Marcgravias, Guttifers, Ochnaceæ and Dipterocarps; and the *Columniferæ*, including the Lindens, Mallows, Sterculiads and Büttnerias.

In the *Eucyclæ* the floral organs are all in whorls, all possess both calyx and corolla, the flowers are hypogynous, tetramerous or pentamerous, the stamens mostly in two whorls, one of which is frequently incomplete, and the syncarpous gynæcium either equals in the number of its component carpels the leaves of the calyx or corolla, or it is composed of twice as many. The seeds are usually exalbuminous. Included in the *Eucyclæ* are the *Gruinales*, represented by the Geraniums, Sorrels, Flaxes, Balsams and Tropæolums; the *Terebinthineæ*, represented by the Rues, Melias, Quassias, Zygophyllums, Burseras and Anacards; the *Æsculineæ*, represented by the Soapberries, Maples, Malpighiads, Milkworts and Erythroxylons; the *Frangulineæ*, represented by the Hollies, Vines, Buckthorns, Pittosporums and Staff-trees.

The *Tricoccæ*, are, some of them, provided with a calyx and corolla, but sometimes they are destitute of one or both; the ovary is superior and three-carpelled and usually trilocular, the stamens and pistils are in distinct flowers but both on the same plant. The Crowberries, Boxwoods, Spurges and Callitriches constitute the group.

The *Calycifloreæ*, have the floral organs mostly in whorls, and the flowers nearly always perigynous or epigynous; most of the species have both calyx and corolla, the stamens are usually as numerous or twice as numerous as the petals, but sometimes in several whorls, and the pistils are most commonly syncarpous or, in a few species, apocarpous.

The principal subdivisions of the Calycifloræ are the *Umbellifloræ*, *Saxifragineæ*, *Opuntieæ*, *Myrtifloræ*, *Thymelineæ*, *Rosifloræ*, and *Leguminosæ*. To the *Umbellifloræ* belong the Parsleys, Aralias and Dogwoods; to the *Saxifragineæ*, the Saxifrages, Hydrangias, Escalonias, Philadelpheæ, Cunonias, Orpines, Currants and Parnassias; to the *Opuntieæ*, the Cactuses; to the *Myrtifloræ*, the Myrtles, Evening Primroses, Loosestrifes, Melastomas, Water-Milfoils, Mangroves and Combretaceæ; to the *Thymelineæ*, the Mezereums, the Oleasters and the Proteas; to the *Rosifloræ*, the Roses, Pears, Hawthorns, Service-berries, Brambles, Plums, Almonds, Dryads, Spiræas, Quillaias and Chrysobalans; and to the *Leguminosæ*, the Pulses, Brasilletos and Mimosas.

To the Dicotyledons belong most of the valuable timber trees, such as the species of Oak, Beech, Chestnut, Willow, Poplar, Walnut, Hickory, Ash, Elm, Mahogany, Maple, Sycamore, Teak, Basswood, Logwood, Lancewood, Rosewood, Ebony and Lignum Vitæ, and a very large number of valuable food-producing plants. From them are obtained the Potato, Tomato, Sweet-potato, Artichoke, Carrot, Celery, Parsnip, Cabbage, Cauliflower, Turnip, Radish, Beet, Buckwheat, Peas, Beans, Lentils, Cassava, Bread-fruit, Chocolate Bean, Coffee, Tea and nearly all our edible fruits and nuts.

Opium and the Cinchona alkaloids, the most valuable of medicines, as well as belladonna, aconite, jalap, scammony, podophyllum, ipecac, digitalis, colocynth, elaterium, gamboge, kino, numerous resins, oleo-resins, gums, gum-resins, balsams, fats and volatile oils are from this source. From the same group are obtained most of the spices, as cloves, allspice, cinnamon, nutmeg, mace, pepper and mustard, and such valuable dye-stuffs as indigo, logwood, Brazil-wood, red-saunders, quercitrin, madder and fustic. It includes the plants which produce cotton, flax and hemp, and those which yield caoutchouc, gutta-percha and balata gum; it includes those strange insectivorous plants, the Sundews, Venus' Fly-trap, the American and East Indian Pitcher-plants, the Bladderworts and Pinguiculas; and, lastly, it includes the great majority of those plants which are cultivated for ornament in our gardens and greenhouses, such as the Roses, Wisterias, Violets, Verbenas, Phloxes, Heliotropes, Forget-me-nots, Primroses, Fuchsias, Gloxinias, Calceolarias, Passion-flowers, Campanulas, Honeysuckles, Rhododendrons, Azaleas, Heaths, Camellias, Buttercups, Lupines, Asters, Poppies, Mallows, Morning-glories and Mignonettes.

CHAPTER XVII.

SUCCESSION OF VEGETABLE LIFE.

Archæan Plants—Palæozoic Plants—Mesozoic Plants.

Order of Appearance in Time. It has been elsewhere stated, that probably the living beings that first appeared on the earth, were simple, undifferentiated forms, neither distinctly animal nor vegetable; but of this we have no positive proof; the conclusion is based upon our knowledge of the laws of evolution, deduced partly from our study of the phenomena of life as we observe them at the present time, and partly from the meager, though significant record of forms preserved in the rocks. All the evidence points decidedly to the simplest of beginnings, but the positive record of these beginnings has been effaced by the changes wrought during the immense period that has since elapsed. The earliest pages of plant history, like those of human history, are blank. The first plants that have left a definite record of themselves are not found in the oldest sedimentary rocks, but in those of comparatively recent origin, and they are not the simplest plants, but those which are well up the scale of development.

Archæan Plants. The lapse of time, during which the Archæan or oldest series of stratified rocks were formed, is probably greater than that of all subsequent geologic times put together. The thickness of these rocks must be fully fifty thousand feet. Yet, in all this series, there has not been found the fossil remains of a single organism that is undeniably such. There has, it is true, been discovered in the Archæan of Canada a supposed fossil protozoan, called Eozoön Canadense, but its fossil character has not yet been settled beyond question; it may be merely a mineral formation. But it would be in the highest degree unreasonable to conclude from this that no life existed. There is every reason to believe that, during the formation of the middle and upper series of these rocks, at least, it existed abundantly. Why the fossil forms have not been preserved is readily understood, when we remember the perishableness of the remains of most of the lower forms of plants, and the profound metamorphism which the rocks of this era have undergone by reason of heat and pressure.

One reason for believing that life abounded in that far off time, is the great quantities of graphite which the rocks contain. It is clearly proved that the graphite of later formations is metamorphic coal, and this we know is carbonized organic matter. There is no reason to doubt that the graphite of the Archæan had the same origin. Moreover, the more modern coal and graphite are shown to be largely the remains of plants and not of animals, and this, it is reasonable to suppose, is true of the graphite of the Archæan.

Another reason is the accumulation of iron ore in beds. The most productive iron-ore beds in the world occur in rocks of this era, the Laurentian rocks of Canada, New York, northern Wisconsin and northern Michigan. It is clearly evident from an examination of these beds that they were deposited as sediment in water. Now, it is known that at the present time the iron ore, which in the form of ferric oxide constitutes the red coloring matter of many soils, is gradually being reduced, by the action of decaying organic matter, to a soluble form, and washed out by means of percolating water and conveyed by streams to lakes and marshes, and there deposited in beds, constituting what is called bog iron ore. Organic matter is necessary to this transfer, and it is difficult to see how in Archæan times, any more than now, such accumulations could have taken place except by the combined agency of organic matter and water.

Still another reason is afforded by limestones which, in the metamorphic form of marbles, are not uncommon in the upper formations of this series. Most of the more modern stratified limestones we know to be composed of calcareous skeletons, chiefly of marine animals such as rhizopods, corals, shell-fish, etc., but partly also of calcareous algæ. The Archæan marbles are also chiefly marine deposits, and are, no doubt, also the metamorphosed remains of animal and plant skeletons.

While, therefore, positive proofs are lacking, the indirect evidence is of the most convincing character, that life—probably both plant and animal—existed in abundance during a considerable portion of this era. Moreover, we can hardly doubt, that, during this time and the immense unrecorded interval that must have elapsed between it and the time the first rocks of the Paleozoic series were deposited, it had developed into numerous, varied and rather complex forms. We ought not to be surprised that, with the dawn of the Paleozoic era, plants and animals—many of them far from being the lowest in the scale—existed in abundance, as shown by their fossil remains.

Paleozoic Plants. In the very oldest rocks of this era—the Primordial or Cambrian—we find, not only animals in abundance, some of them nearly half way up the scale of animal development, but marine algæ, some of them of large size and rather complex structure. The forms are not sufficiently well preserved so that we can determine precisely their relationships, but they appear to belong to the Melanophyceæ, though the species are all quite different from any at present in existence. The fact that their fossil remains are not nearly so abundant as those of the animals, does not imply that the plants themselves were not abundant. Probably then, as now, animals were dependent on plants for subsistence, and an abundance of the former implies an abundance of the latter, but, as we have already seen, in all geological formations plants are less readily preserved than animals, because fewer of them possess mineralized skeletons.

None but marine plants have been preserved to us from this period, and, although it would hardly be fair to conclude from this that no land forms had begun to exist, since these would be less likely to be preserved, they could not yet have attained any considerable development. It is not until we come to the upper formations of the Lower Silurian, that we find distinct traces of plants higher than algæ. Here in the shales, particularly of the Cincinnati group, we find numerous sporangia and macrospores of species of Rhizocarpeæ, which must have resembled, in habits and structure, our modern Salvinia and Marsilea. These plants must have formed an extensive floating or marsh vegetation.

In the Upper Silurian, particularly in its later formations, we find the first clear evidence of land vegetation. Among these were the slender-stemmed Protannularias and Sphenophyllums, having their leaves arranged in whorls. Their affinities have not yet been definitely settled, but they are supposed to have been related to the Rhizocarpeæ. The Psilophytons, with their gracefully coiled branches and fern-like habits, must have formed a dense undergrowth. They were related to the modern Psilotums. But the Nematophytons, some of which attained tree-like dimensions, were apparently the giants of those primeval forests. They were strange plants, of peculiar structure, and uncertain affinities, in some respects resembling huge Fucaceæ, in others, Gymnosperms, but also differing in important particulars from both.

But the terrestrial species were still few in number; land vegetation yet held but a subordinate place in the world's flora.

In the Devonian the species of land-plants became much more abundant, and more highly developed forms were introduced. About one hundred and eighty different species belonging to this period have been described. Among them are found representatives of all the great groups of the Pteridophyta, and a few Gymnosperms. The Equisetineæ are represented by the Asterophyllites, with their star-like whorls of leaves and jointed stems, and the Calamites, which resembled our modern Horsetails, only that they grew to much larger size, and had a more complex stem-structure. The Filicineæ were represented by various species of Ferns, all differing from our modern species. The Lycopodineæ were still represented by Psilophytons, which continued in great abundance, but Lepidodendrons and Sigillarias, huge, tree-like Club-Mosses, but having affinities also with Gymnosperms, are introduced, and constitute a conspicuous part of the forest vegetation of the age. The Gymnosperms are represented by the strange Dadoxylons and Cordaites, quite different from, but clearly forecasting, our modern Conifers.

But the land flora of the Devonian, rich as it is, is poor in comparison to that of the great coal or Carboniferous age which immediately succeeds it. Nearly two thousand species belonging to this age have been described. The plants, though largely of the same types, are not only much more numerous in individuals and varied in species, but the old species and many of the old genera are gone and new ones have taken their place. Lepidodendrons, Sigillarias, Calamites and Ferns become wonderfully numerous, and many of the species attain gigantic dimensions. At no period before or since have the vascular cryptogams attained such a wonderful development. It was emphatically the age of Pteridophytes. The Lepidodendrons, Sigillarias and Calamites were marsh plants, and it was probably chiefly from their remains that the immense coal beds of the period were produced. The Ferns and Conifers, though numerous, contributed comparatively little to coal formation, because they were high-land plants. During this age, also, a new gymnospermous type—the Cycads—was introduced.

Plants of the Mesozoic. With the opening of the Mesozoic or Reptilian age, we find the species and many of the genera have again changed, and forest vegetation presents quite a different aspect. The giant Sigillarias and Lepidodendrons have passed away. Conifers have increased in abundance and variety, and many of the species have a more modern aspect. The Calamites and Ferns still hold their own and tree-ferns are abundant, while the Cycads, which in the Carboniferous had attained but little importance, have wonderfully increased and become the predominant type of forest vegetation. But no new types were added until the latter part of the Jurassic, when a few Monocotyledons allied to the screw-pines and grasses made their appearance. Vascular cryptogams and gymnosperms still ruled the vegetable world.

But in the latter part of the succeeding period, the Cretaceous, a great and apparently sudden change takes place in the flora. The Conifers reach the culminating point of their development in this and the succeeding age, and are represented by such modern types as the Yews, Pines, Junipers, and the noble Sequoias, while the Cycads, on the other hand, begin to decline. The Ferns are still abundant, though less so than formerly, and are now represented by such modern genera as Dicksonia, Gleichenia, Aspidium and Onoclea. It is interesting to note that one species, Onoclea sensibilis, has persisted throughout all the profound changes that have taken place from Cretaceous times down to the present, and is still abundant.

But the most conspicuous change is the great increase in the number of Monocotyledons, and the appearance of Dicotyledons in great abundance and variety. In both of these great groups were also included many modern forms, although the species were nearly all different from those at present existing. Among Monocotyledons were Sedges, Grasses and Palms, and among Dicotyledons, the Beech, Oak, Willow, Poplar, Hickory, Walnut, Chestnut, Birch, Hazel, Alder, Plane-tree, Tulip-tree, Cherry, Buckthorn, Aralia, Sassafras, Laurel, Fig, Persimmon and Sweet-gum. Even such orders as the Leguminosæ and Compostitæ, had their representatives. The forests, in fact, had assumed a decidedly modern aspect.

Of the numerous species of Angiosperms, whose remains are found in the rocks of this period, nearly one-half belong to genera at present in existence; the rest have perished. Some of the forms most abundant at that time are now represented by only one or two lingering species. There are, for example, but two living species of Liquidamber, the Sweet-gum of our Southern States, and a closely allied species confined to Asia Minor; but one species of Sassafras; one of the Plane-tree, and one of the Tulip-tree, the last three all confined to the United States, while in the Cretaceous there were several species of each, and these were widely distributed over the northern hemisphere.

The Coniferous genus, Sequoia, has a similar history. Appearing in the Cretaceous, it flourished through the Tertiary, having its representatives distributed all over the northern hemisphere, while the present species are but two in number, and these confined to California. One is the Red-wood, Sequoia sempervirens, the other the "Big-tree," S. gigantea. Of this genus at least twenty-six fossil species have been described, and no doubt a much larger number have actually existed.

CHAPTER XVIII.—Succession of Vegetable Life (Cont'd).

Plants of the Tertiary—Plants of the Quaternary—
The Defective Record.

Plants of the Tertiary. From the flora of the Cretaceous to that of the Tertiary, the transition is one of easy gradations. The plants of the lower Eocene closely resemble those of the upper Cretaceous, but as time progresses the older forms gradually disappear, to be replaced by modern ones, until the majority of the genera, and even a large proportion of the species, are identical with those found at the present time. The flora at the same time becomes exceedingly rich and varied.

This is the age of the highest development of mammalian animals ; it is also the age when the higher forms of vegetable life reach their culmination ; for not only were all the types, and nearly all the species now existing represented, but there were many more which perished in the vicissitudes of the great ice age which followed.

If we could behold before us the living flora of the Tertiary, we might be surprised at its luxuriance in species, we might wonder that in our own latitude are many plants, such as the Magnolia, Bald Cypress, Pecan and Sweet-gum, that now grow farther south, but we should recognize our own Oaks, Walnuts, Elms, Lindens, Roses and hundreds of other well known forms. The forests and glades would wear a familiar look. At least we should observe no greater differences between this and the flora of our own time, than we may find by comparing those of similar climates in different parts of the world now. In fact, we have, in the present flora of Australia, a fragment of the early Tertiary flora preserved, with scarcely a change to the present time. This is due partly to the exemption of that continent from the extreme vicissitudes of climate which, during the Quaternary, so greatly modified the floras of more northerly regions, and partly to its insular condition, which prevented the intermingling of other floras, and thus rendered less ardent the struggle for existence which elsewhere has so greatly modified manv species and caused the extinction of others.

During the later Cretaceous and early Tertiary, a climate considerably warmer than the present must have prevailed over the northern hemisphere, for a flora similar to that now found in the latitude of the great lakes prevailed as far north as the Arctic Circle. Moreover, there appears to have been a greater uniformity of distribution over the northern hemisphere than at present, which implies not only a more equable climate but a common origin for the floras. Furthermore, the fossil remains of plants afford evidence that there was a gradual lowering of the temperature toward the close of the Tertiary.

Plants of the Quarternary. The changes which took place in the flora of this age, are largely such as may be attributed to the great refrigeration of the glacial epoch. As the glaciers slowly plowed their way southward, the plants as gradually retreated before them until, in the northern portion of the United States, as far south as the Ohio River, the temperate flora had been supplanted by an arctic or sub-arctic one.

Later, when the invading ice and its accompanying cold had withdrawn to the north and a milder temperature had returned, the arctic flora also mostly withdrew to its northern home, and the temperate plants returned to their former habitat.

This, however, did not occur without considerable loss. Although the advance and retreat of the ice must have occupied some thousands of years, or at least were so slow as not to interfere with the migration of species by the ordinary natural means, yet, in some cases, when the ice advanced, lakes, inland seas or other formidable obstacles blocked the path of retreat for the plants, and some species were thus hemmed in and destroyed.

This was especially true in Europe, for here the impassable Mediterranean lay in the path of retreat, and many species of plants were there cut off and exterminated. This is doubtless the reason of the poverty of the European flora as compared with that of eastern North America, and it also accounts for the fact that some types which in Tertiary times were abundant in both Europe and America, now survive only in America. This is the case with the Sequoias, the Tulip-tree and the Sassafras, already mentioned.

We have stated that when the cold of the glacial epoch moderated, the arctic plants that had invaded the temperate zone mostly withdrew to the northward. But this is not true of all. It is an interesting fact, that some of the remains of this flora are still found on high elevations in temperate latitudes. High up in the Alps and Pyrenees are found species which now occur nowhere else in Europe, save in Scandinavia and Finland; and in the White Mountains of New Hampshire and the Green Mountains of Vermont, as well as in portions of the Rocky Mountains, lingers a flora that now finds its counterpart only in Labrador and other parts of northern British America. The only satisfactory explanation for these facts is, that when the rigors of the ice age began to relax and the ice-cap withdrew to its native north, many cold-loving plants, instead of following it in its retreat, found safety and a congenial temperature on these mountain-tops.

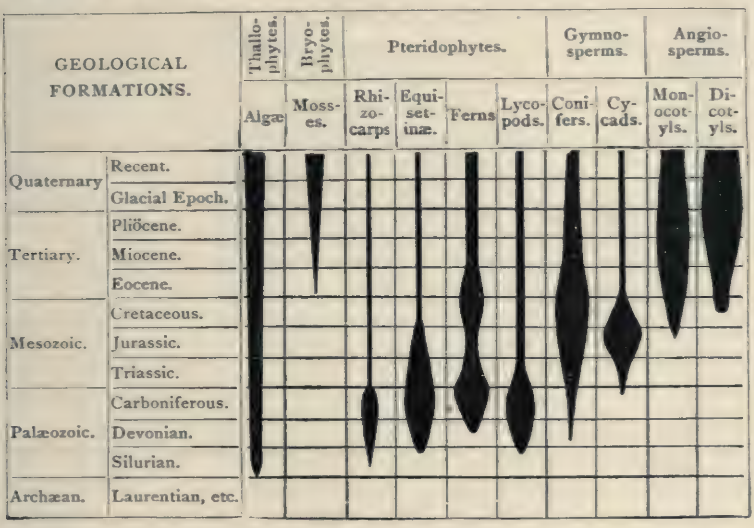

FIG. 579.

The accompanying diagram, Fig. 579, summarizes the most important facts at present known regarding the chronology of plants. The spaces between the horizontal lines represent geologic periods, and the black areas in the vertical columns, the beginning and increase or decrease of the principal types of plants. For example, in the column headed "Lycopods," the black area shows that the oldest known Lycopods occur in the upper Silurian, that the species culminated in the Devonian and Carboniferous, began to decline in the Triassic, and have continued in greatly diminished numbers until the present.

The Defective Record. The record of the succession of life, is, as we have seen, a very fragmentary one. Of all the millions of species of plants that must have existed in geologic time, but a very small fraction could be preserved; (1) because the remains of most plants are very perishable; (2) because the rocks which afford us the only records of the remote past are mostly marine and lacustrine formations, sedimentary deposits, in which only marine species and the few terrestrial or fresh-water ones, that by accident became washed into the seas and lakes, would stand any chance of preservation; (3) because of the disturbances and changes to which many rocks, particularly those of the older series, have been subjected, tending to obliterate all fossil remains. They have often been displaced by earthquake action, metamorphosed by heat and pressure, disintegrated by atmospheric or chemical agencies, or eroded by running water. (4) Because even the imperfect record afforded by the rocks is not continuous; there are great gaps of time entirely unrepresented by rock formations—leaves, and even whole chapters, missing from the record book. Throughout geologic time periods of submergence, when sediments were deposited and rocks formed, alternate with periods of elevation above sea-level, and when erosion instead of rock-building took place. So far as history is concerned, the periods of elevation, however long they may have continued, are often lost intervals, no record of them remaining save the effects of erosion.

But even the very fragmentary record we have, clearly shows a progress from lower to higher. Algæ were the dominant types of the Silurian; vascular cryptogams of the Devonian and Carboniferous; Conifers and Cycads of the Mesozoic, and Angiosperms of all subsequent times to the present. It is what might have been expected on the theory of evolution.

Moreover, it is in accordance with this theory that the types which first appeared were what naturalists call *comprehensive* or *generalized* types; that is, they united in themselves characteristics which now belong to groups quite distinct from each other. For example, the Lepidodendrids of the Devonian and Carboniferous, while, on the whole, more nearly related to the Club-mosses than to any other modern type, had affinities also with the Conifers, not only in the structure of their leaves and stems, but in the fact that they were heterosporous. We may well believe that both Conifers and Club-mosses may have been developed from them by gradual differentiation.

Against the evolution view has been urged the apparent suddenness with which certain types of plants have made their appearance. The considerations already given, showing why the record must be incomplete and fragmentary, afford a sufficient answer to most objections of this kind. But the apparently abrupt advent of Dicotyledons in great numbers in the latter part of the Cretaceous calls for a different explanation, for between the underlying rocks and these, there is no record of a lost interval; the one lie conformably upon the other.

Nor does the theory that the process of evolution goes on much more rapidly during periods of great change in physical geography afford an adequate explanation, for the period does not appear to have been one of great disturbance. The most plausible theory offered in explanation is, that the new flora, so unrelated to that found in the underlying rocks, was an invasion from the north, similar to the arctic invasion that occurred during the ice epoch, and produced by similar causes, only the change of temperature which caused the migration was probably less extreme. The immediate predecessors of this flora are, therefore, to be sought not in the same localities but in the now frozen and inaccessible north.

It is theoretically probable that the first portions of our globe to become sufficiently cooled to support life would be the poles, and it is not improbable that living beings may have swarmed here in myriads, before the now temperate and tropical regions of the world were sufficiently cool to be habitable. From here, as the earth became cooler, they migrated toward the equator. The theory, however, is not unsupported by facts. There is strong evidence derived from the study of the present distribution of plants, in favor of the view that our present floras, at least, originated at the north. Not only do we find in the rocks of frozen Greenland the remains of a temperate flora closely related to our own, but there is a close resemblance between the arctic floras of all the northern continents, and an increasing divergence of forms as we pass along the line of the continent southward. For example, many species of the extreme north of Europe are identical with those of northeastern North America; the flora of central Europe and that on the corresponding isothermals of eastern North America still resemble each other, but the species are mostly different; still greater differences exist between the floras of southern Europe and the southern United States, while the floras of Africa and South America are quite widely different, not only in species but in many of the genera and in some of the natural orders.

In our study of Organography we found the same organ existing under a great variety of modifications, now adapted to one function, now to another, the rhizome, tuber and runner were modified stems, and the bud-scale, petal and stamen were modified leaves; in some plants we found no differentiation of organs, in others it was partial, in still others, complete. Vegetable Histology taught us that all plants had for their structural unit the cell, and that the cell is essentially the same in all plants; some plants, we found consisted of a single cell, others of simple aggregates of like cells, still others of aggregates of cells of different kinds, together forming a complex structure possessing various organs. We found, moreover, that every plant, however complex it may be at maturity, begins its life as a single cell. In our study of Vegetable Taxonomy, also, we were able to trace deep-seated relationship between forms apparently quite distinct. In fact, all our studies of plants lead us irresistibly to the thought of their genetic relationships—to the belief that, in the course of time, all of the immense wealth of plant forms that populate the modern world, were derived by gradual modification from one or a few simple forms in the past. This view, the geological history of plants, fragmentary though it be, tends strongly to confirm and establish.

GLOSSARY OF BOTANICAL TERMS.

GLOSSARY OF BOTANICAL TERMS.

ABERRANT.—Wandering; applied to forms which differ in some particular from the group of which they are members.

Abjoint.—To separate by means of a joint or septem.

Abjunction.—The separation by means of a joint, as in the separation of spores from a growing hypha in some fungi.

Abortive.—Imperfectly developed or rudimentary.

Abscission—A term applied to that mode of the detachment of spores in Fungi which consists in the disorganization of the zone connecting the spores with the hypha.

Abstriction.—Spore formation, either by abjunction or by abstriction.

Acaulescent.—Stemless, or apparently without a stem.

Accumbent.—Cotyledons are described as accumbent when in the embryo they have their faces applied to each other, and the radicle is so folded as to lie in contact with their edges.

Acerose.—Needle-shaped.

Achlamydeous.—Destitute of floral envelopes.

Acicular.—Needle-shaped. (Applied to leaves).

Acinaciform.—Scimitar-shaped.

Acotyledonous.—Without cotyledons. Applied to such embryos as that of Cuscuta, where the cotyledons are aborted.

Acrocarpous.—Bearing fruit at the apex of the growing axis and terminating the growth of the axis in that direction, as in acrocarpous Mosses.

Acrogen.—A name sometimes applied to a plant that grows at the apex only.

Acropetal.—In the direction of the apex.

Actinomorphous.—Applied to flowers that are divisible into similar halves in two or more vertical planes.

Acuminate.—Taper-pointed.

Acute.—Forming a sharp angle.

Aculeate.—Beset with prickles.

Adenophorous.—Glandular or gland-bearing.

Adhesion.—The union of members of different floral whorls.

Adnate.—Literally, grown together. Applied to an anther, the lobes of which are elongated and apparently grown fast to the sides of the filament; also applied to any two different organs that have grown together.

Adventitious.—Occurring out of the regular order. Applied to buds, roots, etc.

Æcidiomycetes.—Æcidium fungi.

Æcidiospores.—The spores produced in an æcidium-fruit, such as the cluster-cups of the Barberry.

Æruginous.—Of the color of verdigris.

Aerophyte.—An air-plant.

Æstivation.—The arrangement of floral organs in the bud.

Agamic.—Without sex; asexual.

Agamogenesis.—A term applied to asexual reproduction.

Agglomerate.—Crowded into a dense cluster.

Aggregated Fruits.—Fruits like the raspberry and blackberry, that consist of a mass of simple fruits, all the product of a single flower.

Akene or Achenium.—A small, dry, indehiscent fruit, like those of the Buttercup and Dandelion.

Alæ.—Wings. Applied to the two lateral petals of a papilionaceous flower.

Alate.—Winged.

Albumen.—A term applied to a nitrogenous organic matter found in animals and plants; also a name applied to the food-store laid up outside the embryo in many seeds.

Albuminous.—Containing albumen. Seeds are said to be albuminous if they possess an extra food supply outside the embryo.

Alburnum.—Sap-wood.

Aleurone.—Proteid matter in the form of small rounded particles, found in seeds.

Alliaceous.—Having an odor like onion or garlic.

Allogamy.—Cross-fertilization.

Alpine.—Growing at high elevations in the Alps; applied generally to plants growing above the tree-line in mountains.

Alternate.—Applied to that form of leaf-arrangement in which only one leaf occurs at a node.

Alveolate.—With honey-comb-like markings.

Ament or Amentum.—A scaly spike or catkin.

Amorphous.—Without definite shape.

Amphicarpous.—Producing two kinds of fruits.

Amphigastria.—A name applied to the small leaves found on the ventral surface of the thallus in the Liverworts.

Amplexicaul.—Clasping or embracing the stem, as an amplexicaul leaf.

Ampulla.—A bladder or pouch.

Amidoplasts. — Proteid granules whose functions it is to form starch grains; also called leucoplastids.

Amphitropous.—Half-inverted. Applied to the ovule when half-inverted on its stalk, so that the latter appears to be attached near the middle of the body of the ovule.

Amylaceous.—Starchy.

Amyloid.—A substance resembling starch.

Amylogenic.—Starch-producing.

Anastomosis.—Opening into each other; a term applied to veins that connect with each other to form a net-work.

Anatropous.—Inverted. Applied to the ovule when completely inverted, so that the hilum and micropyle are brought close together.

Andrœcium.—A term applied to the stamens as a whole.

Androphore.—A stalk supporting an andrœcium, or a body supporting an antheridium.

Androphyll.—A leaf which bears pollen-sacs; a stamen.

Anemophilous. — Literally, wind-loving. Applied to those flowers which depend for cross-fertilization upon the agency of the wind.

Angiocarpous.—Applied to those fungi in which the hymenium or spore-bearing surface is enclosed by the tissues of the sporocarp.

Anisomerous. — Unsymmetrical; applied to flowers the successive whorls of which are unequal in number.

Anisopetalous.—With unequal petals.

Anisophyllous. —Applied to the leaves of a pair or whorls when they are unequal.

Anisostemenous. — Applied to stamens when they are not of the same number as the petals.

Annular.—Ringed. Applied to cells or ducts that have their walls thickened at intervals with ring-like thickenings.

Annulus.—A ring-like layer of cells surrounding the capsule of mosses at the line of separation of the operculum from the body of the capsule. Also applied to the row of special cells surrounding or partly surrounding the sporangia in many ferns.

Anophyta—A name familiarly applied to Mosses and Moss-like plants.

Anther.—That part of the stamen which bears the pollen.

Antheridium. — The male or fertilizing organ of cryptogams; the organ which produces antherozoids.

Antherozoid.—The male reproductive cell of cryptogams.

Anthesis.—The act of flowering.

Anthocyanin. —The dissolved coloring-matter in blue flowers.

Antholeucin. — The dissolved coloring-matter in white flowers.

Anthotaxy.—The arrangement of flowers in clusters. See Inflorescence.

Antipetalous.—Inserted opposite to, instead of alternate with, the petals.

Antipodal Cells.—A term applied to three cells formed in the lower end of the embryo-sac opposite to the cells constituting the egg-apparatus.

Apheliotropism. — The property which some organs possess of turning away from the light.

Aphyllous.—Leafless.

Apocarpous.—Composed of separate carpels.

Apogamy.—The loss of power to reproduce sexually. There may be either a substitution of vegetative reproduction for reproduction by sexual spores, or a substitution of asexual spore-reproduction for reproduction by sexual cells.

Apogeotropism.—The property which some organs possess of growing away from the earth's centre.

Apophysis.—The enlargement of the stalk or seta just beneath the capsule in Mosses.

Apospory.—The loss of the power to reproduce by spores; when the organ ordinarily producing spores develops vegetatively.

Apostrophe.—A term applied to the position assumed by chlorophyll-bodies, when, under the influence of strong light, they gather along the side-walls of the cells.

Apothecium. — The fruiting organ in Lichenes and ascomycetous Fungi in which the hymenium is exposed during the ripening of the ascospores.

Appendiculate.—Furnished with an appendage, as an appendiculate anther.

Aquatilis.—Living in water.

Arboreous.—Tree-like.

Arborescent.—Approaching a tree in size and habits of growth.

Arboretum.—A collection of trees arranged for scientific study.

Arbuscula.—A small shrub having the appearance of a diminutive tree.

Archegonium.—The female reproductive organ of Bryophyta and Pteridophyta.

Archesporium.—A term applied to the collection of cells which make up the layer forming the pollen-sac in the anther.

Archicarp.—A peculiar carpogonium which has no special apparatus for receiving or transmitting the fertilizing element, and whose protoplasm is not rounded off to form an oösphere.

Areolate.—With areolæ or net-like markings.

Aril.—An outgrowth which forms an exterior coat of some seeds, as the mace of nutmegs.

Aristate.—Tipped with a bristle.

Ascending.—Applied to a stem or other organ that rises obliquely upward.

Ascidium.—A pitcher, or a pitcher-shaped organ.

Ascocarp.—The organ which in Ascomycetes and Lichenes produces ascospores.

Ascogonium.—An archicarp, or, generally, an imperfectly developed carpogonium.

Assimilation.—A term applied in botany to the formation of carbo-hydrate from water and carbon-dioxide by the agency of chlorophyll.

Atavism. — The possession of ancestral traits; reversion to the characteristics of remote ancestors.

Atropous.—Erect; not turned. Applied to an ovule which is straight and has the micropyle at one end and the hilum at the opposite end.

Auricle.—An ear, or an ear-like appendage.

Auriculate.—Applied to a leaf that has ear-like appendages at the base.

Autœcious. — Applied to parasitic fungi which pass through all the stages of their existence on the same host.

Autogamous.—A name applied to flowers that are habitually self-fertilizing.

Autoplast—A name sometimes applied to a chlorophyll-body.

Auxospore. — A large spore produced, either asexually or by conjugation, in the Diatomaceæ.

Axil.—The upper one of the two angles formed by the junction of the leaf with the stem.

Axile, or Axial.—Belonging to the axis, or situated on the axis; a term describing that form of placentation in which the ovules are borne on the axis of the ovary.

BACCATE.—Berry-like.

Balustra.—A name applied to a fruit like that of the pomegranate.

Basidiospores.—The spores of the higher fungi, which are produced by abjunction from a large cell called a basidium.

Basidium.—A large cell borne on the hymenium of a fungus, which gives origin to basidiospores.

Basifugal.—In a direction away from the base. Applied to that form of leaf-growth in which the growing area is situated near the apex of the leaf.

Basilar.—Situated at the base. Applied to the style when inserted at or near the base of the ovary.

Basipetal.—In a basal direction. Applied to that form of leaf-growth in which the growing area is situated near the base of the leaf.

Bassorin.—A gum which swells extensively in water but does not properly dissolve. It occurs in gum tragacanth.

Bast.—A term applied to the inner layer of the bark in Dicotyledons and Gymnosperms.

Bast-fibers. — The thick-walled, fibrous tissue found in the inner layer of the bark. The term is also commonly extended so as to include other similar tissues found elsewhere in the plant.

Berry.—An indehiscent fruit with a pericarp which is succulent throughout, as the Grape and Gooseberry.

Bi-collateral.—Applied to fibro-vascular bundles like those of the Pumpkin stem, each of which consists of a xylem mass between two masses of phloëm.

Bi-crenate.—Doubly scalloped. Applied to a leaf whose margins have a double set of scallops.

Bi-dentate.—Doubly-dentate. Applied to a leaf whose margin has a double series of outwardly projecting teeth.

Bi-facial.—Two-faced. Applied to a leaf which has a distinct palisade tissue next the upper epidermis.

Biflorous.—Two-flowered.

Bifurcate. — Possessing two forks or prongs.

Bi-labiate. — Two-lipped. Applied to those gamophyllous corollas and calyxes that have a more or less distinctly two-lipped appearance.

Bilocular.—Possessing two loculi.

Biology.—The science of living beings.

Bi-pinnate.—Twice pinnate. Applied to a leaf which is twice compounded on the pinnate plan.

Bi-radiate.—Possessing two rays.

Bi-serrate.—Doubly serrate. Applied to a leaf whose margin has a double series of teeth which incline toward the apex of the leaf

Bi-sexual.—Possessing both male and female organs ; hermaphrodite.

Bi-sulcate.—Having two furrows.

Bi-ternate.—Twice compounded on the plan of three.

Bostryx.—A belicoid cyme.

Botryose.—The botryose type of inflorescence is one which is constructed on the plan of a raceme.

Bracteoles.—(See Bractlets).

Bracts.—The modified leaves borne on flower peduncles or at base of flower clusters.

Bracklets, or Bracteoles.—The smaller bracts borne on pedicles.

Bryology.—The science of Mosses, also called Muscology.

Bulb.—A short underground stem covered with fleshy leaf-bases or fleshy leaves, as the Onion and Squill.

Bulbil, or Bulblet.—Small bulbs of fleshy buds frequently occurring on above-ground parts of plants, as the bulblets of some onions and of the Tiger-lily.

Bullate.—Blistered or puckered. Applied to certain leaf-surfaces.

Bundle-sheath.—A limiting layer or cells either marking off a fibro-vascular bundle from the surrounding tissue, or separating a mass of woody bundles, forming the woody cylinder, from the surrounding cortex.

CADUCOUS.—Applied to the calyx when it falls off before the flower expands.

Cæspitose.—Growing in bunches ; forming a tuft or turf.

Calcarate.—Spurred, as a spurred calyx or corolla.

Callose.—Bearing callosities or hard protuberances.

Callus. —A peculiar thickening deposit found in the sieve-plates of sieve-cells.

Calycine.—Belonging to the calyx.

Calyculate.—Bearing bracts below the calyx which imitate the latter in appearance.

Calyculus.—The same as epicalyx.

Calyptra—A cap, the remains of the archegonium, raised on the top of the capsule in mosses.

Calyx.—The outer whorl of floral envelopes.

Cambiform Cells.—Prismatic, thin-walled cells associated with sieve-tissues in the phloëm.

Cambium.—The forming tissue at the junction of the wood and bark in the stems of Dicotyledons and Gymnosperms.

Campanulate.—Bell-shaped.

Campylotropous. —Applied to an ovule whose body is bent so as to bring the micropyle and chalaza nearly to the same level.

Canaliculate. — Channelled or grooved longitudinally.

Canescent.—Possessing a long pubescence.

Capillary.—Slender, hair-like.

Capillitium. —Thread-like fibers commonly arranged in the form of a net-work, and serving, by their elasticity, to loosen and scatter the spores in the fructification of the Myxomycetes.

Capitulum.—A head. Applied to a flower-cluster such as that of the clover, and also to a rounded cell borne by the manubrium in the antheridium of the Characeæ.

Capreolate.—Tendril-bearing.

Capsule.—A dry, usually dehiscent fruit, made up of two or more carpels.

Carbohydrate. — A substance belonging to the starch series of compounds, composed of carbon, hydrogen and oxygen, the latter two elements in the same proportion as in the water molecule.

Carpel.—A leaf modified so as to bear ovules. Applied to a simple pistil or to one of the leaf components of a compound pistil.

Carpellary. —Pertaining to the carpels.

Carpogonium.—The name applied to the female reproductive organs in some Thallophytes. Its peculiarity consists in the great change it undergoes after fertilization, resulting in the development of a sporocarp.

Carpophore.—The stalk or support of fruits, corresponding to the receptacle in the flower. Also an organ, in some Thallophytes, which bears spores.

Carpospore.—A spore developed within a fertilized carpogonium or sporocarp.

Caruncle.—Applied to the keel-like appendage which occurs on some seeds.

Caryophyllaceous. — Applied to flowers like the Pink, having five long-clawed petals and a tubular calyx.

Caryopsis.—An indehiscent dry fruit, like that of the wheat, in which the single seed is enveloped in the closely-adhering pericarp.

Catkin.—An indeterminate flower-cluster, in which the flowers are sessile on a lengthened axis, and borne in the axils of scales.

Caudate.—Possessing a tail-like appendage.

Caudex.—Applied to a scaly unbranching tree-trunk, like those of palms and tree ferns.

Caulescent.—Having a more or less conspicuous stem.

Caulicle.—The stemlet of the embryo plant.

Cauline.—Pertaining to the stem. Cauline leaves are those which spring from that portion of the stem which is above the ground.

Caulis.—The stem, or ascending axis of the plant.

Caulome.—A general term which includes all forms of stems.

Cellulose.—Primary cell-wall substance.

Centric.—A term applied to the internal structure of such leaves as show no distinctly developed pallisade tissue, and no considerable structural differences between the upper and under surfaces.

Centrifugal.—Flying away from the centre. Applied to cymose inflorescence; the same as determinate.

Centripetal.—Seeking the centre. Applied to indeterminate inflorescence.

Cereal.—A term applied to wheat and similar grains.

Chaff.—A term applied to the peculiar flattened hairs often found on the stipes of Ferns. See Palea.

Chalaza.—The area at the base of the ovule where the coats are united to each other and to the nucellus.

Chartaceous.—Paper-like in texture.

Chlorophyll.—The leaf-green of plants. The substance by whose agency carbohydrate is formed in green plants.

Chlorophylless.—Destitute of chlorophyll.

Chlorophyll-Bodies.—Proteid bodies in the cells of plants, which contain the chlorophyll.

Chlorosis.—Changing to green. Applied to abnormal flowers, the parts of which have changed back to green leaves. Also used to indicate a diseased condition in which plant has become blanched and lost its normal green color.

Chloroplastid.—The same as chlorophyll-body.

Choripetalous. — Applied to a corolla whose petals are distinct.

Chorisepalous. — Applied to a calyx whose sepals are distinct.

Chorisis.—The development of two or more members where but one is expected; a doubling.

Cicatrix.—A scar, as that left by the fall of a leaf.

Cilia. — Hair-like, vibratile protoplasmic processes attached to certain spores and other cells by means of which they move.

Circumnutation.—A bowing successively toward all points of the compass. Applied to the movements of young and growing organs.

Circumcissile.—Applied to that form of dehiscence in which the capsule opens transversely, as by a lid.

Circinate.—Rolled like a crozier. Applied to the form of vernation in which the leaf is rolled inward from the apex toward the base, as in most Ferns.

Cirrhose.—Provided with tendrils.

Cirrhosely-pinnate. — Pinnate with the upper leaflets replaced by tendrils, as in the Pea.

Cladophyll.—A branch which in form mimics a leaf.

Clavate. — Club-shaped. Applied to a stigma or other organ that is thick toward the apex and gradually narrowed toward the base.

Claw.—The stalk, or contracted base of a petal.

CLEISTOCARP.—An ascocarp in which the spores are completely enclosed and from which they escape by the rupturing of its walls.

CLEISTOGAMOUS.—Applied to flowers which are self-fertilizing and do not expand.

CLYPEATE.—Shaped like a buckler.

COARCTATE.—Crowded together.

COCHLEA.—A coiled legume, like that of Medicago.

COCHLEATE.—Spirally coiled like a snail-shell.

CŒNOBIUM.—A colony of independent cells held together by a common investment.

COHESION.—Applied to the union of parts of the same kind or which belong to the same whorl.

COHORT.—A term used in classification.

COLEORHIZA.—A sheath which envelopes the radicle in some embryos and through which roots penetrate when the seed germinates.

COLLATERAL.—Placed side by side. A term applied to those fibro-vascular bundles which consist of a phloëm-mass and a xylem-mass arranged side by side.

COLLECTIVE FRUITS.—Fruits which are the product of numerous distinct flowers growing in compact clusters. Same as multiple fruits.

COLLENCHYMA.—Thick-angled tissue. A modification of parenchyma in which the walls of the cells are thickened at the angles.

COLUMELLA.—A term applied to the persistent axis of the capsule, found in many Bryophyta.

COLUMN.—A term applied to the united stamens and pistils in the Orchids.

COMPLANATE.—Flattened.

COMA.—A tuft of hairs attached to some seeds, as those of the Milkweed and Dogbane.

COMOSE.—Bearing a coma.

CONCENTRIC.—Having a common centre, as of several circles or whorls one within the other; for example, the rings of growth of a tree. Concentric fibro-vascular bundles are those in which one portion of the bundle, either xylem or phloëm is located centrally and the other is arranged around it.

CONCEPTACLE.—Applied to a cavity which bears the fruiting organs in some Algæ and Fungi.

CONDUPLICATE.—Doubled together. The vernation of a leaf is conduplicate when the two sides are folded together face to face on the midrib.

CONFLUENT.—Blending gradually together into one.

CONIDIA.—Applied to the deciduous asexual reproductive spores produced by many fungi, such as those of the Bread-mould, Penicillium. See also Gonidia.

CONIDIOPHORE.—The single hyphæ or aggregate of hyphal filaments which bear conidia. Also called gonidiophore.

CONJUGATION.—That form of sexual reproduction in which two cells, similar in size and appearance, unite to form a spore.

CONNATE.—Grown together, as is sometimes the case with the bases of two opposite leaves.

CONNECTIVE.—That portion of the anther which connects the two lobes.

CONNIVENT.—Converging toward each other; applied to stamens which converge above, as those of the Violet.

CONTORTED.—Twisted together. That form of æstivation in which the sepals or petals are so placed that one edge of each is exterior, and one interior, or overlapped by the adjacent one, producing a twisted appearance.

CONTRACTILE.—Possessing the power of contracting or shortening.

CONVOLUTE.—Rolled up. Applied to leaves or other flattened organs that are rolled from one edge.

CORDATE.—Heart-shaped. Applied to a leaf or other flattened organ which has a deeply and sharply indented base, as the leaves of Lilac and Basswood.

CORIACEOUS.—Thickish and leathery in texture.

CORM.—A short, erect and thickened underground stem with scaly leaves.

CORMOPHYTA.—A term formally applied to vascular cryptogams and flowering plants—to all plants possessing roots, stems and leaves.

CORNEOUS.—Horny in texture, as horny albumen, etc.

COROLLA.—The inner whorl of floral envelopes.

CORONA.—A crown-like appendage to the petals of certain flowers, as of the Pink.

CORONATE.—Possessing a corona.

CORPUSCULUM.—A name applied to the central cell in the archegonium in Coniferæ.

Cortex.—Bark. The primary cortex is that part of the fundamental system of the stem or root which is outside of the fibro-vascular bundles.

Corymb.—A flower-cluster on the indeterminate plan, in which the axis is somewhat shortened and the pedicels of the lower flowers somewhat lengthened, so as to form a flat-topped cluster.

Corymbose.—Corymb-like or arranged in corymbs.

Costate. — Ribbed; applied to leaves having two or more large veins running from base to apex.

Cotyledon.—One of the parts of the embryo, homologous with a leaf and sometimes performing in part the functions of one, but usually serving as a store-house of food for the growing plantlet.

Cremocarp.—The peculiar capsular fruit of the natural order Umbelliferæ.

Crenate.—Scalloped.

Crenulate.—Finely crenate.

Cribriform.—Sieve-like. Cribriform tissue is the same as sieve tissue.

Cribrose.—Sieve-like.

Crispate.—Crisped on the margin. Applied to certain leaves and fronds.

Cross-fertilization. — The impregnation of the female organ of one plant by the male gamete from another.

Cross-pollination.—The dusting of the stigma of one flower with the pollen from another.

Crown.—(See Corona).

Cruciform. — Cross-shaped. Applied to flowers with four distinct petals arranged in the form of a cross, as the flowers of the Mustard.

Crustaceous.—Hard and brittle. Also forming a crust or closely adherent coating, as the crustaceous Lichenes.

Cryptogams.—A general term applied to plants below Phanerogamia; any flowerless plant is called a cryptogam.

Crystalloids.—Crystal-like proteid bodies found in seeds, tubers, etc.

Cucullate.—Hooded; a term descriptive of the form of certain leaves and floral organs.

Culm.—The peculiar jointed stem of the grasses.

Cuneate.—Wedge-shaped.

Cupule.—A cup like that of the acorn.

Curvinerved. — Applied to leaves whose veins are curved and nearly parallel in their course.

Cuspidate. — Applied to a leaf which is abruptly terminated by a short, hard point.

Cutin.—Cork-substance; a modification of cellulose also called *suberin*.

Cutinization.—The formation of cutin.

Cyathiform.—Cup-shaped.

Cyclic.—Applied to flowers whose organs are arranged in whorls.

Cyme.—A loose flower-cluster on the determinate or centrifugal plan.

Cypsela.—A term sometimes applied to an achenium which is invested with an adnate calyx such as that of the Compositæ.

Cystocarp.—A name sometimes applied to the sporocarp in the Florideæ.

Cystolith.—A stalked body, mainly composed of calcium carbonate, found in the cells of certain leaves, as in those of the Nettle.

Decandrous.—Possessing ten stamens.

Decapetalous.—Possessing ten petals.

DECIDUOUS.—Falling off. Applied to leaves that fall in autumn, and to the calyx and corolla when they fall off before the fruit develops.

Declinate.—Bent downward.

Decompound.—Many times compound.

Decumbent.—Bent to one side; reclining.

Decurrent.—Applied to leaves which are prolonged down the side of the stem below the point of their insertion.

Decussate.—Literally, crossed. Applied to opposite leaves when the successive pairs each stand at right angles with the pair next below them.

Definite.—Limited or defined. In botany applied to the annual growth of some trees, such as the Hickory, that complete the annual work of vegetation, and form their buds for the succeeding year before the close of the season. Also applied to anthotaxy in the same sense as determinate, q. v.

Defoliation. —The process by which a leaf separates from the stem in autumn.

Dehisce.—To split open. Applied to the splitting open of anthers to shed their pollen, of antheridia to set free their antherozoids, of sporangia to shed their spores, of certain fruits to shed their seeds, etc.

Dehiscence. —The act of dehiscing or splitting open.

Deliquescent.—Dissolving; applied to a stem that divides into branches.

Deltoid.—Triangular, somewhat like the Greek letter Δ. A term descriptive of the shape of certain organs, as some leaves, ovaries and stigmas.

Dentate.—Applied to leaves or other flattened organs that have their margins toothed with acute teeth that point perpendicularly outward from the margin.

Denticulate.—Dentate with minute teeth.

Depauperate.—Impoverished. Applied to a plant or organ that from lack of nourishment or by reason of other unfavorable conditions has not attained full development.

Dermatogen.—The layer of cells, in a young or growing part, that is destined to become epidermis.

Determinate.—Applied in botany to an inflorescence in which the blossoming takes place centrifugally, the blossoms being from terminal and not from axillary buds.

Dextrine.—A substance resembling starch, but soluble in cold water.

Diadelphous.—In two brotherhoods. Applied to stamens when cohering bv their filaments into two sets.

Disastase.—An unorganized ferment found in germinating cereals, etc.

Diageotropic.—Applied to an organ that grows in a direction at right angles to that in which the force of gravity is exerted.

Diandrous.—Possessing two stamens.

Diarch.—A term descriptive of radial fibrovascular bundles having two rays.

Dicarpellary.—Possessing two carpels.

Dichasium.—An inflorescence on the plan of a false dichotomy.

Dichlamydeous.—Applied to flowers that possess both calyx and corolla.

Dichotomous.—Forking; dividing into two equal branches.

Dichotomy.—A forking.

Diclinous.—Having the stamens and pistils in separate flowers.

Dicotyledon.—A plant whose embryo has two opposite cotyledons; the name of a sub-class of the Phanerogamia.

Didynamous.—Having the stamens in two pairs, one of the pairs longer than the other.

Diffuse.—Widely spreading. Applied to the habit of growth of certain stems and branches.

Digitate.—Applied to a compound leaf in which the leaflets all radiate from the top of the petiole.

Dimerous.—In two parts. Referring to a flower constructed on the numerical plan of two.

Dimidiate.—Applied to an anther whose lobes are widely separated by a broad connective.

Dimorphism.—Possessing two forms of flowers, one with short styles and long stamens, the other with long styles and short stamens.

Diœcious.—In two households. With staminate and pistillate flowers separate and on separate plants.

Dipetalous.—Two-petaled.

Discocarp.—The same as Apothecium.

Discoid.—Disc-like. Descriptive of the shapes of certain stigmas, receptacles, etc.

Dissepiment.—A partition in a fruit.

Distichous.—In two perpendicular rows; applied to the arrangement of leaves or other organs.

Divergent.—Inclining away from each other.

Dolabriform.—Shaped like an axe.

Drupe.—A stone-fruit, as those of the Cherry, Peach and Plum.

Drupelet.—A small drupe.

Duct.—A tube formed by the confluence of two or more cells, found in the fibrovascular system of plants. Synonymous with *vessel*.

Dumose.—Bushy, or pertaining to a bush.

Dumetose.—Belonging to a thicket.

Duramen.—Heart-wood.

ECHINATE.—Beset with prickles.

Echinulate.—Beset with prickles of small size.

Egg-apparatus.—The oösphere and the two companion cells called the synergidæ in the upper end of the embryo-sac, are termed the egg-apparatus.

Elaters.—Thread-like, usually spirally coiled bodies found in the sporangia of Liverworts and Equisetum. They aid in ejecting the spores when they are ripe.

Eleutheropetalous.—The same as choripetalous.

Eleutherosepalous.—The same as chorisepalous.

Emarginate.—Notched. Applied to a leaf which is notched at the apex.

EMBRYO.—Applied in botany to the plantlet within the seed.

EMBRYO-SAC.—The female reproductive cell of flowering plants; a cell in the ovule in which the embryo begins to form after fertilization.

ENCHYLEMA.—The more fluid portion of protoplasm.

ENDECANDROUS.—Possessing eleven stamens.

ENDOCARP.—The inner layer of the pericarp.

ENDOCHROME.—The brownish-colored portion of the cell-contents in Diatomaceæ.

ENDODERMIS.—A sheath, consisting of one or more layers of cells, which encloses certain kinds of fibro-vascular bundles.

ENDOGENS.—A term formerly applied, but rather inappropriately, to the group of plants now called Monocotyledons.

ENDOGENOUS.—Growing from the inside, or springing from the interior tissues.

ENDOPHLŒUM.—The inner layer of the bark of the stems of Dicotyledons and Gymnosperms.

ENDOPHYTE.—A plant growing within another plant.

ENDOPLEURA.—The inner seed-coat, also called tegmen.

ENDOSPERM.—A mass of cells which develops within the embryo-sac, and which usually constitutes the albumen of seeds.

ENDOSPORIUM.—The inner coat of a spore.

ENSIFORM.—Sword-shaped.

ENTOMOPHILOUS.—Literally, insect loving. Applied to those flowers which are cross-fertilized by the agency of insects.

EPHEMERAL.—Lasting but for a day.

EPIBLEMA.—The name applied to the peculiar epidermal cells of the root, taken collectively.

EPICALYX.—A name applied to a whorl of bracts below the calyx and resembling it.

EPICARP.—The outer layer of the pericarp.

EPICORALLINE.—Upon the corolla.

EPICOTYL.—That part of the embryo stem which is above the cotyledon or cotyledons.

EPICOTYLEDONARY.—Above the cotyledons.

EPIDERMIS.—The boundary tissue of plants, usually consisting of a single layer of compactly arranged cells.

EPIGYNOUS.—Upon the pistil. Applied to other floral organs when they appear to be separately inserted on the summit of the ovary.

EPINASTY.—Curvature produced by growth on the upper side of an extended organ.

EPIPETALOUS.—Upon the petals. Applied to stamens when inserted upon or adnate to the corolla.

EPIPHLŒUM.—The outer layer of the bark of Dicotyledons and Gymnosperms.

EPIPHYTAL.—Pertaining to Epiphytes.

EPIPHYTE.—A plant that grows upon another plant but does not derive its sustenance from it.

EPISPERM.—The outer seed coat, also called the testa.

EPISTROPHE.—A term applied to the position assumed by chlorophyll bodies when, by reason of diminution of light, they place themselves along the upper and lower walls of the cells.

EQUISETINÆ.—The class of Pteridophyta which includes the Scouring-rushes or Horse-tails.

EQUITANT.—Literally, riding. Applied to leaves like those of the Iris, which are vertical and folded lengthwise so that each leaf, toward the base, overlaps or straddles the next.

EROSE.—Irregularly toothed, as if gnawed.

ERYTHROPHYLL.—Leaf-red. A red coloring matter found in autumn leaves, ripe fruits, etc.

ETÆRIO.—A fruit, the product of a single flower, which consists of small aggregated drupes, as the fruit of the Raspberry.

ETIOLATION.—The bleaching which occurs in green plants when kept for a time in a dark place,

EUCYCLIC.—A term applied to a flower that has the same number of parts in each whorl and the successive whorls alternate with each other; the same as symmetrical.

EXALBUMINOUS.—Applied to seeds that are destitute of albumen, or of an extra food-store laid up outside of the embryo.

EXCURRENT.—Applied to a tree-trunk, like that of the Balsam Fir, which does not become dissolved into branches, but maintains its predominance over them.

EXOTHECIUM.—The epidermis of the anther.

EXOCARP.—The outer layer of the pericarp.

EXOGENOUS.—Growing from without, or springing from exterior tissues, as the growth of the leaf from the stem. Also applied, though hardly correctly, to the growth in thickness of the stems of Dicotyledons and Gymnosperms.

Exogens.—A term formerly applied, but not quite correctly, to the plants now called Dicotyledons.

Exosporium.—The outer coat of the spore.

Exserted.—Protruding, as stamens from the throat of a corolla.

Exstipulate.—Not possessing stipules.

Extine.—The outer coat of the pollen-grain.

Extrorse.—Facing outward. Applied to anthers which face away from the pistil.

FALCATE.—Scythe or sickle-shaped.

Farinaceous.—Mealy. Applied to the albumen of some seeds when it has a mealy consistency.

Farinose.—Covered with a mealy deposit.

Fascicle.—A bundle. Applied to a compact cyme, or to a compact cluster of leaves.

Fascicular.—Belonging to a bundle. The cambium belonging to an open fibro-vascular bundle is called *fascicular cambium.*

Fasciculate.—Clustered, as fasciculate leaves, roots, etc.

Fenestrate.—With large window-like perforations.

Fertilization.—The form of sexual reproduction which consists essentially in the union of two cells different in size and appearance.

Fibro-vascular Bundles.—The bundles of stringy, vascular tissues of plants.

Fibrous Tissue.—Elongated, thick-walled and taper-pointed cells or cell derivatives, found mainly in the fibro-vascular bundles. The tissue includes bast cells, wood cells and wood tracheids.

Filament.—Literally, a thread. The term applied to the stalk which supports the anther.

Filiform.—Thread-like.

Filiform-apparatus.—The longitudinally striated upper ends of the synergidæ which form a kind of cap projecting through the upper end of the embryo-sac in many plants.

Fimbriate.—Fringed. Applied to certain leaves, petals, etc., whose margins have fine, fringe-like teeth.

Fimbrillate.—Finely fringed.

Fission.—That mode of cell division in which the cell separates into two equal or nearly equal portions.

Flabellate, or Flabelliform.—Fan-shaped; applied to leaves, etc.

Flagellate.—Producing slender runners.

Flagellum.—A whip-like protoplasmic process or large cilium which is attached to some cells and serves as an organ of locomotion.

Fluviatile.—Belonging to, or growing in, running water.

Foliaceous.—Leaf-like. Applied to floral organs, etc.

Foliose.—Leaf-bearing.

Follicle.—A monocarpellary pod that dehisces along the ventral suture only.

Foramen.—The orifice in the coats of the ovule through which the pollen-tube penetrates. Also applied to the corresponding part in the seed. Same as Micropyle.

Fovilla.—The contents of the pollen-tube.

Frond.—A thallus, or organ in which the functions of leaf and stem are not fully differentiated.

Frondose.—Thalloid, or like a thallus.

Fructification.—The production of fruits of whatever sort.

Frumentaceous.—Belonging to grain.

Fruticose, or Fruticous.—Shrubby.

Fugacious.—Soon falling off. Applied to certain sepals, petals, etc.

Fuliginous.—Sooty-brown in color.

Fulvous.—Having a tawny yellow color.

Fundamental Tissues.—Those tissues of the plant through which the fibro-vascular bundles are distributed; they include all the tissues, interior to the epidermis, not included in the fibro-vascular bundles.

Funiculus.—The same as podosperm. The stalk of the ovule.

Furcate.—Forked; divided into two equal branches.

Fuscous.—Grayish-brown.

Fusiform.—Spindle-shaped; larger in the middle and diminishing in diameter toward either end.

GALBULUS.—A succulent, berry-like cone, as the fruit of the Juniper.

Galeate.—Shaped like a helmet.

Gamete.—A sexual reproductive body, either motile or non-motile, which by union with another reproductive body, either similar or dissimilar to it, produces a cell which sooner or later develops into a new organism.

Gamogenesis.—A term applied to the process of sexual reproduction.

Gamopetalous.—Having the petals more or less united.

Gamophyllous.—Having the leaves (either sepals or petals) of the floral whorls more or less united.

Gamosepalous.—Having the sepals more or less united.

Gemma.—A kind of bud, which becomes separated from the parent plant and gives rise to a new plant.

Gemmation.—The process of budding or of giving rise to gemmæ.

Geniculate.—Kneed; abruptly bent, as a geniculate root.

Geotropism.—That property of a stem or other organ which causes it to grow toward the earth's centre.

Germinal Vesicle.—The imperfectly formed germ cell in the embryo-sac previous to fertilization.

Germination.—The sprouting of a seed or reproductive spore.

Gibbous.—With a swelling on one side.

Glabrous.—Smooth; destitute of hairs or protuberances. Applied to leaf or other plant surfaces.

Glandular.—Bearing glands.

Glans.—A nut. The name applied to fruits like the filbert, acorn, chestnut, etc.

Glaucous.—Covered with a bloom, as the leaves of the Cabbage, etc.

Globoids.—Globular or amorphous particles of the double phosphate of calcium and magnesium often found associated with crystalloids in protein granules.

Glomerule, or Glomerulus.—A compact cluster of sessile flowers on the determinate plan.

Glucosides.—Vegetable principles which are readily decomposable by the action of ferments or dilute acids into glucose and another substance capable of still further decomposition.

Glumaceous.—Possessing chaff-like bracts or glumes.

Glume.—A chaffy bract, such as those found in the inflorescence of the grasses.

Gluten.—A form of proteid matter found in Wheat and some other cereals.

Glutinous.—Covered with a sticky exudation.

Gonidia.—Used sometimes in the same sense as conidia. In Lichenes, the gonidia are the algal constituents of the thallus.

Gonidiophore.—The single hyphæ or aggregate of hyphal filaments which bear gonidia or conidia. (See Conidiophore).

Granulose.—The principal constituent of starch grains, the other being starch-cellulose.

Gymnocarpous.—Naked-fruited; applied to those fruits of Fungi which have the hymenium naked or exposed.

Gynophore.—A stalk supporting the female organ.

Gymnospermous.—Naked-seeded. Applied to those plants whose ovules are unenclosed, as the Pines, Cycads, etc.

Gynæcium.—The name applied to the pistils of a flower taken as a whole.

Gynandrous.—Having the stamens and pistils more or less united.

Gynostemium.—The column formed by the adhesion of the stamens to the pistils. See Column.

Habitat.—The geographical range or habitation.

Hæmatoxylin.—The coloring principle of logwood.

HALF-SUPERIOR.—Applied to the ovary when the calyx adheres to the lower portion, while the upper portion is free.

Haplopetalous.—Possessing a single whorl of petals.

Haplostemenous.—Possessing a single whorl of stamens.

Hastate.—Shaped like a halberd.

Haustorium.—A sucker-like process that serves for attachment and for sucking up nourishment.

Head.—The same as *Capitulum*. A compact cluster of sessile or nearly sessile flowers arranged on the indeterminate plan.

Helicoid.—Shaped like a helix or snail-shell. Applied to certain flower-clusters, etc.

Heliotropism.—That property of a plant or plant organ by virtue of which it bends away from the sunlight.

Heptamerous.—Consisting of seven parts or members; constructed on the numerical plan of seven.

Heptandrous.—Possessing seven stamens.

Herbaceous.—Applied to stems or other organs that have a tender, juicy consistence and perish at the close of the growing season.

Herbarium.—A collection of dried plants arranged for study.

Hermaphrodite.—Applied to flowers that possess both stamens and pistils.

Hesperidium.—A glandular-rinded berry, such as the orange, lemon, etc.

Heterocarpous. — Producing different kinds of fruits.

Heterocyst.—Applied to the large cells occurring at intervals in the filaments of the Nostocaceæ.

Heterœcious.—Applied to a plant like Puccinia graminis, which spends a portion of its life on one host and then another portion, in a different form, on another host.

Heterogamous.—Producing more than one kind of flowers.

Heteromerous.—Applied to the organs or parts of a flower when they do not correspond in number. Heteromerous Lichenes are those which have the algal and fungal elements in different layers.

Heteromorphous.—Having flowers of different forms as regards the size or relative position of the essential organs.

Heterophyllous.—Having leaves of different shapes.

Heterostemenous. — Having stamens of different forms.

Heterosporous. — Producing more than one kind of asexual spore. Applied to those vascular cryptogams which produce both macrospores and microspores on the same plant.

Heterostyled. — Applied to hermaphrodite flowers, when in the same species different flowers have styles of different length.

Hexamerous.—Consisting of six parts or members. Applied to a flower that is constructed on the numerical plan of six.

Hexandrous.—Possessing six stamens.

Hexapetalous.—Possessing six petals.

Hexasepalous.—Possessing six sepals.

Hilum.—The point of attachment of an ovule or a seed to its funiculus, or if sessile, to the placenta.

Hip.—The peculiar aggregated fruit of the Rose.

Hippocrepiform. — Shaped like a horseshoe.

Hirsute.—Covered with rather stiff, coarse hairs.

Hispid.—Bristly. Beset with rigid, spreading hairs.

Histology.—The science of the minute structure of an organism.

Homocarpous.—Having fruits all of one kind.

Hoary.—Grayish-white in color.

Homogamy.—When hermaphrodite flowers mature their stigmas and anthers at the same time.

Homoiomerous.—Made up of similar parts. A term applied to those Lichens which have the algal elements of the thallus about equally dispersed among the fungal elements.

Homologous.—Having the same essential nature or belonging to the same type; *e. g.*, petals, ordinary leaves and bud-scales are homologous organs.

Homomorphous. — Applied to organs or parts that have the same form.

Homosporous.—Producing but one kind of asexual spores. (See Heterosporous).

Homoystyled.—Applied to hermaphrodite flowers when all those in the same species have styles of about equal length.

Hybrid.—A cross between two species.

Hydrophilous.—Applied to flowers that are pollinated by the agency of water-currents.

Hydrophyte.—A water-plant.

Hygroscopism.—The property of absorbing moisture or of swelling or undergoing change of form by reason of absorbing moisture.

Hydrotropism.—The property possessed by some roots of bending toward water.

Hymenium.—The layer of spore-bearing cells in or on a sporocarp.

Hymenophore.—The part of a fungus bearing the hymenium.

Hypha.—A thread-like chlorophylless, usually branching body, which grows apically and usually becomes divided into cells by the formation of transverse septa, and constituting a part of the thallus of a Fungus.

Hypocotyl.—That portion of the embryo stem situated below the cotyledons.

Hypocotyledonary. — Below the cotyledons.

Hypocrateriform. — Salver-shaped. Applied to corollas and calyxes.

Hypoderma.—The colorless cells immediately under the epidermis of leaves. Also applied to the external portion of the cortex immediately under the epidermis of stems.

Hypodermal. — Beneath the epidermis; belonging to the hypoderma.

Hypogæal, or Hypogæous.—Growing underground.

Hypogynous.—Underneath the pistils. Applied to stamens or other floral organs that are free from the pistil and inserted on the receptacle beneath it.

Hyponasty. — Curvature produced by growth on the under side of an extended organ.

Hypsophyll.—A bract.

IDIOBLAST.—A single cell which in form, size or contents differs considerably from the surrounding cells of a tissue.

Imbricate.—Applied to that arrangement of leaves or floral organs in the bud, in which they overlap like shingles on a roof.

Immersed. — Applied to leaves or other organs when they grow wholly under water.

Impari-pinnate. — Pinnate, with an odd leaflet at the apex.

Inæquilateral. — Unequal-sided, as the bases of some leaves.

Incised.—Gashed, or sharply and rather deeply cut. Applied to leaf margins, etc.

Included.—Applied to stamens or pistils that do not project beyond the corolla, but are contained within it.

Incumbent.—Applied to cotyledons when the radicle is folded back so as to be in contact with the outer face of one of them.

Indefinite. — Not limited. Applied to petals and other organs when too numerous to be conveniently counted. Also applied to inflorescence in the same sense as indeterminate, q. v.

Indehiscent.—Not splitting open. Applied to certain fruits, etc.

Indeterminate.—Applied to that type of inflorescence in which the flowers are the products of axiliary buds and the inflorescence is centripetal.

Indigenous.—Native to the country.

Induplicate. —Applied to that form of valvate æstivation in which the margins of the leaves are inflexed or folded inward.

Indusium.—A membrane which in many cases covers the fruit-dots or sori of Ferns.

Inferior.—Applied to an ovary which has an adherent calyx.

Inflorescence. — The arrangement of flowers in clusters. (See Anthotaxy).

Infra-axillary.—Below the axil.

Infundibuliform.—Funnel-shaped.

Innate.—Applied to anthers which are attached by their base to the apex of the filament.

Inosculating.—The same as Anastomosing.

Insertion.—The place or manner of attachment of a part or organ on the organ which bears it.

Inter-fascicular.—Between the bundles. Inter-fascicular cambium is that portion of the cambium zone which lies between the fibro-vascular bundles in the stems of Gymnosperms and Dicotyledons.

Internal Cell Formation.—That mode of cell division in which new cells are formed within the walls of an old cell.

Internode.—That portion of a stem which lies between the points of insertion of two successive leaves or of two successive whorls of leaves.

Interruptedly-pinnate. —Applied to a pinnate leaf that has small leaflets intermixed with larger ones.

Interstitial.—Situated between. Applied to that form of growth which consists in the interposition of new particles between old ones instead of in additions to the surface.

Intine.—The inner coat of the pollen-grain.

Introse.—Applied to stamens that face inward or toward the pistil.

Inulin.—A principle isomeric with starch, which replaces that substance in many Compositæ and some other plants.

Involucre.—The name applied to the whorl or whorls of bracts at the base of a flower cluster.

Involucel.—A secondary involucre, as the whorl of bractlets that subtend the umbellets of many of the Umbelliferæ.

Involute.—A form of vernation in which the leaves are rolled inward from their edges.

Irritability.—The property of responding to stimulus.

Isogamous.—A term used to designate that mode of reproduction in which the uniting gametes are of equal size. The same as conjugating.

Isomerous.—Having an equal number of parts in the successive whorls.

Isostemenous.—Having the stamens of the same number as the petals.

KYANOPHYLL.—The bluish-green pigment in chlorophyll.

Karyokinesis.—A term descriptive of the changes which the nucleus undergoes during the process of cell division.

LABELLUM.—A lip, or modified petal, such as that of Cypripedium and other Orchids.

Labiate.—Lipped. The same as bi-labiate.

Labium.—A lip. The lower lip of a bilabiate corolla; or the most conspicuous petal of the flowers of Orchids.

Lacerate.—Irregularly cleft, as if torn.

Laciniate.—Cut irregularly into narrow lobes. Applied to the margins of leaves, petals, etc.

Lacunæ.—A term specially applied to air-spaces when about the size of the surrounding cells.

Lacunose.—Having pits or depressions.

Lacustrine.—Belonging to or living in ponds or lakes.

Lageniform.—Shaped like a Florence flask.

Lamella.—A little plate. The term middle lamella is applied to the middle portion of the common cell-wall of two adjacent cells.

Lamellar.—Composed of lamellæ or thin plates.

Lamina.—The blade or expanded portion of a leaf or petal.

Lanate.—The same as Lanuginous.

Lanceolate.—Shaped like a lance.

Lanuginous.—Covered with soft, wooly hairs.

Latex.—Milk. The milk-juice of plants.

Laticiferous.—Milk-bearing. Applied to the milk-tissues of plants.

Legume.—A monocarpellary pod, like that of the Pea or Bean, that dehisces along both the ventral and dorsal sutures.

Legumin.—A proteid compound in the seeds of many plants belonging to the natural order of Leguminosæ.

Lenticels.—Small oval dots which appear upon the branches of cork-forming Dicotyledons during the first year's growth, and which, by further growth during the early part of the second year, rupture the epidermis.

Lenticular.—Shaped like a double-convex lens.

Lepidate.—Scurfy or covered with small scales.

Leptosporangiate.—Having sporangia formed from a single cell.

Leucanthus.—White-flowered.

Leucoplastids.—Starch-forming, colorless, proteid bodies found in cells not exposed to light; amyloplasts.

Liber.—The inner layer of the bark in Gymnosperms and Dicotyledons.

Libriform-cells.—Those cells of the wood which are excessively thick-walled and resemble bast or liber-fibers.

Lichenin.—A starch-like body found in Cetraria and some other Lichens.

Ligneous.—Woody, or having a woody texture.

Lignified.—Converted into lignin or covered with ligneous deposits.

Lignin.—A modification of cellulose, constituting the greater portion of the weight of most dry wood.

Ligulate.—Strap-shaped, as the corollas of many of the Compositæ; also a membranous appendage at the summit of the leaf-sheath in many grasses.

Ligule.—A name applied to the strap-shaped corolla of many of the Compositæ; also a membranous appendage at the summit of the leaf-sheath in many grasses.

Liliaceous.—Applied to a lily-like flower, or one with a funnel- or bell-shaped, six-leaved perianth.

Limb.—The spreading portion of a gamophyllus calyx or corolla.

Linear.—Applied in botany to an organ that is narrow, many times longer than broad, and has parallel margins.

Lingulate.—Tongue-shaped.

Lithocysts.—Crystal-cells.

Litoral.—Belonging to or inhabiting the shore.

Lobe.—A rounded projection from the margin of a leaf or other flattened organ.

Lobate or Lobed.—Possessing lobes.

Loculicidal.—Applied to the dehiscence of a capsule when it splits open longitudinally along the middle of the back of the cell.

Loculus.—One of the cells of a pistil or fruit, which contains ovules or seeds.

Loment.—A modified legume that breaks up transversely, when ripe, into joints.

Lomentaceous.—Bearing loments.

Lorate.—Long strap-shaped.

Lucid.—Shining.

Lunate.—Crescent-shaped, or shaped like a half-moon.

Lutescent.—Yellowish, or becoming yellow.

Lyrate.—Applied to a pinnatifid leaf, the terminal lobe of which is more prominent than the rest.

Lysigenous.—A term descriptive of intercellular spaces when they are produced by the destruction of cells.

MACROSPORES.—The larger of the two kinds of spores produced by the Selaginellas and others of the higher Pteridophyta.

Macrosporangium.—A sporangium which contains macrospores.

Maculate.—Blotched or spotted.

Mamillate.—Bearing teat-like protuberances.

Mammæform.—Teat-like in form; shaped like a cone whose apex is rounded.

Marescent. — Withering without falling off.

Marmorated.—Traversed by veins, as in some kinds of marble.

Medulla.—The pith.

Medullary Rays.—Rays of fundamental tissue which connect the pith with the cortex, and separate the fibro-vascular bundles, in the stems of Dicotyledons and Gymnosperms.

Medullary Sheath.—A sheath composed of spiral ducts and wood cells surrounding the pith, in Dicotyledons and Gymnosperms.

Meiostemenous. — Having the stamens fewer in number than the petals.

Membranous. — Applied to an organ or part that is flattened, thin and flexible.

Mericarp.—A portion of a fruit separating from the rest, as the two parts of the cremocarp in the Umbelliferæ.

Meristem. — Forming tissue; cells in a state of active division and growth, as those of the cambium layer, etc.

Mesocarp.—The middle layer of the pericarp.

Mesophlœum.—The middle layer of the bark.

Mesophyll.—The interior parenchyma of the leaf.

Mestom.—That part of a fibro-vascular bundle whose function is mainly conducting; for example, the ducts.

Metabolism. — The oxydizing processes that go on in the living plant.

Metaplasm.—A term sometimes used to designate the granular matter in protoplasm.

Metastasis.—Used in botany in the same sense as metabolism.

Micellæ.—The crystalline particles, which, according to Naegeli's theory, form the solid constituents of organic matters.

Micropyle.—The orifice in the coats of the ovule through which the pollen-tube penetrates. Also applied to the corresponding part in the seed. (Same as foramen).

Microsomes.—The very minute granular particles seen in protoplasm.

Microsporangium.—A sporangium which contains microspores.

Microspore.—The smaller of the two kinds of spores produced by the heterosporous Pteridophytes.

Midrib.—The main or middle rib of a pinnately-veined or pinnately-nerved leaf.

Mitriform.—Shaped like a mitre.

Monadelphous.—In one brotherhood. Applied to stamens which are united by their filaments into one set.

Monanthous.—One flowered.

Moniliform. — Resembling a string of beads. Applied to the shapes of certain hairs, roots, tubers, etc.

Monocarpic, or Monocarpous.—Fruiting but once.

Monochasium.—A cyme which has one main axis.

Monochlamydeous.—Having but one set of floral envelopes.

Monocotyledonous.—Possessing but one cotyledon or seed-leaf.

Monoclinous.—Having both stamens and pistils or both sets of sexual organs. Used in the same sense as hermaphrodite.

Monœcious.—Belonging to one household. Applied to plants which have separate staminate and pistillate flowers, but both borne on the same plant.

Monolocular. — Having but one cell or loculus.

Monomerous.—Applied to flowers that are constructed on the numerical plan of one.

Monopetalous.—Sometimes used in the same sense as gamopetalous; literally and strictly, possessing but one petal.

Monopodial. — Applied to that form of branching in which all the branches originate as lateral appendages.

Monopodium.—An axis that sends off lateral branches in acropetal succession.

Monosepalous. — Literally, one-sepalled; but often used in the same sense as gamosepalous.

Monostichous.—Arranged in a single vertical row.

Monostylous.—Having a single style.

Motile.—Possessing the power of motion.

Mucronate.—Applied to a leaf which is abruptly tipped with a small, soft point.

Multicellular.—Consisting of many cells.

Multifid.—Many-cleft, or cleft into many lobes or segments.

Multilocular.—Possessing many loculi.

Multipinnate.—Many times pinnate.

Multiple Fruit. — A fruit composed of numerous small fruits, each the product of a separate flower, as the Mulberry and Pineapple. Same as *collective fruit.*

Multiserial.—In many series.

Muricate.—Roughened with short, rigid excrescences.

Muscology.—The Botany of Mosses. Same as Bryology.

Muticous.—Blunt, not pointed.

Mycelium. — The vegetative hyphæ of fungi, usually forming interwoven or tangled masses in the substratum.

Mycology.—The botany of the Fungi.

NAPIFORM.—Turnip-shaped.

Navicular, or Naviform.—Boat-shaped, as the glumes of many grasses.

Nectary.—The honey gland or honey repository of a flower.

Nervation.—Applied to the parallel form of venation.

Nerved.—Parallel-veined.

Node.—The point on the stem of a plant where the leaf is inserted.

Nodose.—Jointed or swollen at intervals.

Nucellus.—A term applied to the body of the ovule or that part within the coats.

Nucleolus.—A minute spot in the nucleus of a cell; literally, a little nucleus.

Nucleus.—The rounded, granular portion of the protoplasm in which the process of cell division begins. That portion of the ovule included within the coats is also called the nucleus, but this use of the term should be abandoned.

Nuciform.—Shaped like a nut.

Nuclein.—That portion of the nucleus which readily absorbs coloring matter.

Nucule.—A small nut; a term often applied to the female organ in the Characeæ.

Nutant.—Nodding.

Nutation.—Used in the same sense as circumnutation, which see.

Nyctitropic.—Applied to movements connected with the phenomenon called the "sleep of plants."

OBCONICAL.—Conical, but with the point of attachment at the apex.

Obcordate.—Inversely heart-shaped.

Oblanceolate. — Inversely lanceolate, or tapering more toward the base than toward the apex.

Oblong.—Applied to leaves, petals, etc., that have a flowing outline and are two or three times longer than broad.

Obovate.—Inversely egg-shaped. Applied to leaves.

Obsolete.—A term applied in botany to an imperfectly developed or rudimentary organ.

Obtuse.—Blunt. Applied to leaves, etc.

Obvolute.—The term applied to that form of vernation in which half of one leaf covers half of another; half-equitant.

Ochrea.—A stipular sheath, formed by the coalescence of the stipules around the stem.

Ochroleucous.—Yellowish-white.

Octamerous.—Applied to whorled organs having eight parts in each whorl.

Offset.—A short, rooting branch. A short stolon.

Oligarch.—A term descriptive of radial fibro-vascular bundles which have few rays.

Oligandrous.—Having few stamens.

Oliganthous.—Having few flowers.

Oligospermous.—Few-seeded.

Oögamous.—Applied to the union of gameetes when they are dissimilar in form and size.

Oögonium.—The female reproductive organ of the Oöphyta.

Oöphore.—The stage in the development of Bryophyta and Pteridophyta in which the sexual organs are borne.

Oösphere.—The unfertilized germ-cell in the oögonium.

Oöspore.—A spore developed in a fertilized oögonium; a fertilized and matured oösphere.

Operculate.—Possessing an operculum.

Operculum.—A lid; the top of a capsule that separates transversely by an even line, as the operculum of Mosses.

Orbicular.—Applied to leaves or other flattened organs that have a nearly circular outline.

Orchidaceous.—Having orchid-like flowers, that is, flowers with a six-leaved, irregular perianth, and the lower leaf developed into a lip.

Organography.—A description of organs; in botany, a description of the organs that make up the plant body.

Orthostachy. — A perpendicular row of leaves on the stem.

Orthotropous.—The same as atropous, q. v.

Osmosis or Osmose.—Terms applied to the diffusion of liquids through animal and vegetable membranes.

Oval.—Forming a broad ellipse.

Ovary.—The part of the pistil which contains the ovules.

Ovate.—Applied to a leaf or other flattened organ whose outline resembles that of an egg.

Ovate-lanceolate.—Between ovate and lanceolate.

Ovate-oblong.—Between ovate and oblong.

Ovoid.—Egg-shaped. Applied to solid bodies.

Ovulate or Ovuliferous. — Ovule-bearing.

Ovule.—The rudimentary seed; that part of the pistil which contains the embryo-sac.

PALATE.—A swelling or projection in the throat of that form of the bi-labiate corolla called personate.

Pales or Palea.—One of the inner bracts of the inflorescence of grasses. Also applied to the flattened brown hairs or chaff found on the stems and leaves of ferns.

Palisade Tissue.—The green parenchyma next the upper surface of a bi-facial leaf, consisting of cells elongated in a direction perpendicular to the epidermis.

Palmatifid.—Palmately cleft

Palmatilobate.—Palmately-lobed.

Palmatisect.—Palmately divided.

Palmi-nerved. — With simple veins radiating from the base to the margin of the lamina.

Palmi-netted, or Palmi-reticulate.—Netted-veined, with the main veins radiating from the base toward the margin of the blade.

Paludose. — Belonging to or inhabiting marshy places.

Panduriform. — Fiddle-shaped. Applied to certain leaves and other flattened organs.

Panicle.—A compound raceme.

Papilionaceous.—Butterfly-like. A term descriptive of the shape of flowers like those of the Pea and related plants.

Papillose.—Bearing papillæ.

Pappus.—The modified calyx limb of the florets of the Compositæ.

Papyraceous.—Having a papery texture.

Paraphysis.—A jointed filamentous body found associated with the reproductive organs of some plants, as the Mosses.

Parasitic.—Applied to organisms that obtain their sustenance at the expense of other organisms.

Parastichies.—A term used to describe the secondary spirals in the compact forms of alternate phyllotaxy.

Parenchyma.—A tissue made up of thin-walled cells which are commonly bluntened and not much longer than broad.

Parenchymatous. — Pertaining to parenchyma.

Parietal.—Belonging to the walls. Applied to placentæ that are borne on the walls of the ovary.

Pari-pinnate.—Pinnate with an even number of leaflets.

Parted.—Applied to a leaf that is separated into parts almost to the midrib or base.

Parthenogenesis.—The production of an embryo without the intervention of the male fertilizing element.

Patelliform.—Circular and disc-like, resembling the patella or knee-pan.

Pauciflorous.—Few-flowered.

Pectin. — The substance found in fruits which forms the basis of vegetable jelly.

Pectinate.—Comb-shaped. Applied to a leaf or petal that is parted or divided into rigid segments arranged like the teeth of a comb.

Pedate.—Palmately parted and with the lateral divisions more or less two-lobed.

Pedicel.—A partial peduncle, or the stemlet of an individual flower of a cluster.

Peduncle.—A flower-stalk. The stalk of a flower-cluster is called a *common peduncle.*

Peltate.—Shield-shaped. Applied to a leaf whose petiole is attached near the centre of the lamina.

Pelviform.—Shaped like a shallow cup.

Pendulous. — Hanging obliquely downward. Applied to an ovule or seed that hangs obliquely downward.

Penicillate.—Shaped like a pencil of hairs.

Pentacarpellary.—Composed of five carpels.

Pentadelphous. — A term descriptive of stamens which are united by their filaments into five sets.

Pentamerous.—Applied to a flower that is constructed on the numerical plan of five.

Pentapetalous.—Having five petals.

Pentaphyllous.—Having five leaves.

Pentasepalous.—Having five sepals.

Pentarch.—A term descriptive of radial fibro-vascular bundles having five rays.

Pentastichous.—Arranged in five vertical rows.

Pepo.—The name applied to fruits like the Gourd, Pumpkin and Watermelon.

Perfoliate.—Applied to a leaf when the stem appears to pass through its base.

Perianth.—A term applied to the floral envelopes taken as a whole.

Periblem.—A zone of meristem lying between the plerome and the dermatogen at the growing end of an axial organ.

Pericambium.—A layer of formative tissue within the endodermis that surrounds certain fibro-vascular bundles.

Pericarp.—The walls of the ripened ovary; the part of the fruit that encloses the seeds.

Perichætium. —The leafy envelope surrounding the archegonia or both antheridia and archegonia in Mosses.

Periderm.—The name applied to the continuous layers of cork that cover the stems of many plants after they have acquired a certain age.

Peridium.—The outer covering of the fructification in the angiocarpous fungi.

Perigonium.—Sometimes used in the same sense as perianth. In Mosses, the leafy envelope surrounding the antheridia.

Perigynium.—A term applied to the scale-like or bristle-like bodies surrounding the pistils in sedges. Also, the envelope which in Liverworts invests the archegonia.

Perigynous. — Applied to stamens and petals when they are adnate to the throat of the calyx, and therefore borne around the pistil instead of at its base.

Perisperm.—A food store found in some seeds, which consists of nutrient matter deposited in the nucellus outside the embryo-sac.

Peristome.—A fringe of hair-like or fenestrated bodies surrounding the orifice of a Moss capsule.

Perithecium.—A cup or flask-shaped organ producing ascospores on its interior.

Persistent.—Applied to leaves that remain on the tree over winter, and to a calyx that persists until the fruit ripens.

Personate.—Applied to a bi-labiate flower that has the throat closed by a prominence called the "palate."

Pervious.—Possessing an opening or passage way.

Petal.—One of the leaves of the corolla.

Petaloid.—Colored like a petal.

Petiolar. — Belonging to a petiole or attached to one.

Petiole.—The stem or stalk of a leaf.

Petiolate.—Possessing a petiole.

Petiolule.—The stalk of a leaflet.

Phelloderm. — Green cells beneath the cork, formed from the inner layers of the phellogen.

Phellogen.—Cork-meristem, or the tissue which by cell division gives rise to cork.

Phloëm.—That portion of the fibro-vascular bundle which contains sieve tissue.

Phlœum.—Bark.

Phloroglucin. — An aromatic substance having the formula $C_6 H_6 O_3$ found in the bark of Cherry and other plants. Used as a test for lignin.

Phycocyanin. — A bluish coloring-matter which occurs in the Cyanophyceæ.

Phycoerythrin.—A reddish coloring-matter occurring in some Algæ.

Phyllocyanin. — A blue coloring matter extracted from chlorophyll.

Phyllome.—A general term that includes the leaf in all of its modifications.

Phylloxanthin.—A yellow coloring-matter extracted from chlorophyll.

Phycophæin.—A brownish coloring-matter occurring in some plants, particularly in some of the marine Algæ.

Phycology.—That department of botany which treats of Algæ.

Phycoxanthin.—A yellowish-brown coloring-matter found in some Algæ.

Phylloclade, or Phyllocladium. — A branch which, in form and function, mimics a leaf.

Phyllotaxis, or Phyllotaxy.—The arrangement of leaves on the stem.

Physiology.—The science which treats of the functions of organic beings.

Phytography.—Plant description.

Phytology. — The science of plants; Botany.

Pileus.—The cap-like upper portion of the fructification in the Hymenomycetes.

Pilose, or Pilous.—Covered with long, straight, soft hairs.

Pinnate — Applied to compound leaves when the leaflets are laterally arranged along a lengthened axis.

Pinnatifid. —Pinnately-cleft.

Pinnatilobate.—Pinnately-lobed.

Pinnatipartite.—Pinnately-parted.

Pinnatisect.—Pinnately-divided.

Pinni-nerved.—Nerved or simple-veined on the pinnate plan.

Pinni-netted.—Netted veined on the pinnate plan.

Pisiform.—Resembling a pea in shape.

Pistil.—The modified leaf or leaves which bear the ovules.

Pistillate.—Applied to flowers that possess pistils but not stamens.

Placenta.—The ovule-bearing portion of the ovary.

Placentation.—The arrangement of the placentæ.

Placentiform.—Circular and flat in shape.

Plasmodium.—A term applied to the protoplasmic, multinucleated body of one of the Myxomycetes when in the amœboid stage of development.

Plasmolysis.—A contraction of the protoplasm produced by certain reagents.

Plastid.—A general term for rounded proteid bodies such as leucoplastids, chlorophyll bodies, etc.

Plerome.—The axile portion of a growing point surrounded by the periblem. The undeveloped central cylinder.

Pleurenchyma.—A term sometimes applied to woody tissues.

Plicate.—Folded like a fan.

Plumose, or Plumous.—Feathery; branching like a feather.

Plumule.—The primary bud of the embryo.

Plurifoliolate.—Applied to a compound leaf which has many leaflets.

Plurilocular.—Having many cavities or loculi.

Poculiform.—Shaped like a drinking-cup.

Podosperm.—The stalk of the ovule or seed. The same as funiculus.

Pollen.—The fertilizing powder produced by the anther.

Pollination.—The act of conveying the pollen to the stigma.

Pollinium.—A pollen mass. Applied to the masses of united pollen grains of Orchids and some other plants.

Polyadelphous. — Applied to stamens which are united by their filaments into many sets.

Polyandrous.—Possessing many stamens.

Polyanthous.—Many flowered.

Polyarch.—A term descriptive of radial fibro-vascular bundles which have many rays.

Polycarpellary.—Composed of two or more carpels either distinct or united.

Polycarpic.—Fruiting many times.

Polycephalous.—Bearing many heads.

Polycotyledon. —A plant which in embryo possesses more than two cotyledons.

Polyembryony. — Producing more than one embryo within an ovule.

Polygamous. — Applied to plants which produce staminate, pistillate and hermaphrodite flowers all on the same plant.

Polygynous.—Possessing many pistils.

Polymerous.—Of many parts. Applied to whorls composed of many pieces; an ovary that is composed of two or more united carpels is also sometimes called polymerous.

Polymorphous.—Having several or many different forms.

Polypetalous.—Possessing many petals. Applied by the older botanists to flowers having the petals distinct or ununited.

Polyphyllous.—Many-leaved. Applied to the calyx or corolla, and also to the leaflets of compound leaves.

Polyrhizal.—Possessing many roots.

Polysepalous.—Possessing many sepals. Used by the older botanists in the sense of having the sepals distinct or ununited.

Polyspermous.—Many-seeded.

Pome.—A fleshy fruit like that of the Apple, which is syncarpous, succulent, and whose bulk is made up chiefly of enlarged and adherent calyx.

Porous.—Possessing pores. Applied to the dehiscence of anthers where the pollen escapes by a minute pore-like opening, and to capsules where the seeds escape through similar small openings in the pericarp.

Prefloration.—The arrangement of the floral organs in the bud. The same as æstivation.

Prefoliation.—The arrangement of the leaves in the bud. The same as vernation.

Premorse.—Applied to roots or other organs that end abruptly, as if bitten off.

Prickles.—Hardened and rigid hairs, appendages to the outer bark of plants.

Primary Cortex.—That portion of the growing apex of an axial organ which lies between the plerome and dermatogen; the pleriblem.

Primine.—The outer of the two coats of the ovule.

Primordial Cell.—A term applied to a cell of the simplest character, one which does not possess a cell wall.

Primordial Utricle.—A term applied to the outer layer of the protoplasm, which is somewhat denser than the rest, and is immediately applied to the cell wall.

Procumbent. — Prostrate. Applied to a stem that lies flat on the ground.

Proembryo.—An organ which, in some of the higher cryptogams, is developed from the oöspore, and from which the mature form of the plant is afterwards developed. The suspenser or chain of cells which in flowering plants precedes the development of the embryo is also properly called a proembryo.

Proliferous.—Bearing offshoots.

Prosenchyma.—A term used to designate the elongated, taper-pointed cells and vessels of plants.

Prosenchymatous.—Belonging to prosenchyma.

Protandry or Proterandry.—The maturation of the stamens before the stigmas in hermaphrodite flowers.

Proteids.—A class of nitrogenous organic compounds, including gluten, legumin, vegetable fibrin, etc.

Protein.—A nitrogenous organic compound forming the basis of the proteids.

Proterandrous or Protandrous.—Terms descriptive of hermaphrodite flowers that mature their stamens before the stigmas are ready to receive the pollen.

Proterogynous or Protogynous.—Terms descriptive of hermaphrodite flowers that mature their stigmas before they do their stamens.

Prothallium.—The name applied to the thalloid structure produced by the germination of the spore in Pteridophyta, and which bears the antheridia and archegonia.

Protomeristem or Primary Meristem.—The young and imperfectly developed cells which form the beginning of an organ or tissue.

Protophloëm.—The first formed elements of the phloëm of a bundle.

Protophyta.—A term sometimes applied to those lowest forms of plant life that do not reproduce sexually.

Protoplasm.—The living matter of the cell.

Protoxylem.—The first formed elements of the xylem of a bundle.

Pruinose, or Pruinous. — Applied to leaves or other organs that appear as if covered with hoar-frost.

Pseudo-bulb.—The fleshy bulb-like internodes of epiphytal Orchids are called pseudo-bulbs.

Pterocarpous.—Wing-fruited.

Pteridium, or Pterodium —The same as samara; a winged achenium.

Pteridographia.—The botany of Ferns.

Puberulent.—Covered with a fine, soft, almost imperceptible down.

Pubescent. — Downy; covered with soft hairs.

Pugioniform.—Shaped like a dagger.

Pullulation.—That form of cell multiplication in which the mother-cell forms a minute protuberance on one side which afterwards increases to the size of the parent cell. It is also called budding. This is the ordinary form of cell multiplication in the Yeast plant and its allies.

Pulverulent.—Covered with powdery or granular matter.

Pulvinate.—Possessing a cushion-like enlargement or pulvinus.

Pulvinus.—An enlargement at the base of some leaves or of the leaflets of some compound leaves.

Punctum Vegetationis.—The vegetating point. Applied to the growing-point of an organ, as of a stem or root.

Pustular.—A term descriptive of a surface which has blister-like elevations.

Putamen.—The endocarp of a drupe or stone-fruit; the pit or stone of such a fruit as a Peach or Cherry.

Pyramidal.—Shaped like a pyramid.

Pyriform.—Pear-shaped.

Pyxidium.—The same as pyxis.

Pyxis.—A capsule whose dehiscence is circumcissile, or which opens by a circular, horizontal line, so that the upper part comes off like a lid.

Quadrifoliate.—With four leaves.

Quadrifoliolate. — With four leaflets; applied to a compound leaf which has four leaflets.

Quinate.—Applied to a palmately compound leaf with five leaflets.

Quincuncial.—Applied to that form of æstivation where there are five leaves, two outside, two inside, and one with one edge outside and the other inside. Also five-ranked

Quinquefoliolate.—Applied to any compound leaf that has just five leaflets.

Quinquefoliate.—Five-leaved.

Quinquelocular.—Applied to an organ that has five loculi, as a five-celled ovary

Raceme.—That form of indeterminate inflorescence in which the flowers are pedicelled and arranged along a lengthened axis.

Racemose.—Arranged in a raceme.

Rachis.—The axis of inflorescence.

Radical.—Belonging to the root. Radical leaves are those which, like the leaves of the Dandelion, appear to spring from the root, but which in reality arise from a very short stem at or near the surface of the ground.

Radicant.—Rooting.

Radiciflorous. — With the flower apparently springing immediately from the root or underground parts.

Radicle.—A little root. The term applied to the primary root of the embryo.

Radix.—The root.

Radial. — Arranged in rays.. A radial fibro-vascular bundle is one which has the xylem arranged in rays, with intervening rays or masses of phloëm.

Radiate Venation.—That form of venation in which the main veins radiate from the top of the petiole.

Rameal, or Ramal. — Belonging to branches.

Ramenta.—A term applied to the paleæ or chaffy hairs found on the stems and petioles of many ferns.

Ramose.—Branching.

Ramulose.—Bearing numerous branchlets.

Ramulus.—A branchlet, or small branch.

Ramus.—A branch.

Raphe.—(See rhaphe).

Raphides.—Needle-like crystals found in the cells of some plants.

Receptacle.—The shortened stem on which the floral organs are inserted. Also the shortened axis of a flower-head.

Reclinate.—Reclined or bent downward. Applied to stems, branches, etc. Also applied to that form of vernation in which the apex of the leaf is bent downward toward the base.

Reduplicate.—Double-back. Applied to to that form of valvate æstivation in which the margins of the organs are turned outward.

Reflexed.—Bent outward or toward the dorsal side. Used with reference to leaves, petals, etc.

Regma.—A term applied to a fruit like that of the Geranium, in which the carpels separate elastically from the base of the carpophore.

Rejuvenescence—Literally, the renewal of youth. Applied to that mode of cell formation in which the whole of the protoplasm escapes from the cell wall and forms a new cell.

Reniform.—Kidney-shaped.

Repand.—Applied to a leaf margin, which is toothed like the margin of an umbrella.

Replicate. — That form of vernation in which the apex of the leaf is bent backward toward the base.

Replum.—The septum of certain pods that persists after the valves have fallen away.

Repent.—Creeping, as of stems that creep along the ground.

Reticulate.—Netted. Applied to venation, the surface markings of organs, etc.

Retuse.—Applied to a leaf or other flattened organ that has a broad, shallow sinus at the apex.

Revolute.—That form of vernation or æstivation in which the margins of the organ are rolled backward.

Rhachis.—(See rachis).

Rhaphe, or Raphe.—The adherent portion of the funiculus in amphitropous and anatropous ovules.

Rhizocarpous.—A term sometimes applied to herbaceous plants whose roots live on from year to year.

Rhizogenic.—Root-producing. A term applied to the cells in the pericambium, just in front of a xylem ray of a fibro-vascular bundle, which give origin to root-branches.

Rhizoids.—Organs resembling roots but simpler in structure, borne by some Thallophytes.

Rhizome, or Rhizoma.—A root-stock or subterranean stem.

Rhizomorphous. — In shape and appearance like a root.

Rhomboidal.—Shaped like a rhomb. A term sometimes applied in leaf description.

Rimose.—Cracked or chinked, as the bark of many trees.

Ringent. — Gaping. Applied to labiate flowers with widely parted lips.

Riparius.—Growing along river-banks.

Rivalis.—Growing beside brooks.

Rosaceous.—Rose-like. A botanical term descriptive of flowers that have five spreading, clawless or short-clawed petals, as the flowers of the Apple, Rose, etc.

Rostrate.—Beaked, or possessing a beak-like point, as certain anthers.

Rotate.—Wheel-shaped.

Rotund.—Having a rounded outline.

Rufous.—Brownish-red.

Rugose.—Applied to a surface that is rough or wrinkled.

Ruminated.—Applied to the albumen of seeds when channeled or perforated with holes.

Runcinate.—Applied to a leaf like that of the Dandelion that is pinnately incised or cleft and has the segments hooked backward.

Runner.—A stem or branch like that of the Strawberry, that creeps along the ground, rooting at intervals.

SACCATE.—Applied to corollas that have a sac-like projection on the tube.

Sacculate.—With small, sac-like projections. Diminutive of saccate.

Sagittate. —Arrow-shaped. Applied to leaves that are shaped like the head of an arrow.

Samara.—An indehiscent dry fruit provided with a wing-like appendage, as the fruits of the Ash and Elm.

Saprophyte.—A chlorophylless plant which derives its sustenance from decaying organic matters.

Sarcocarp.—The fleshy part of a drupaceous fruit.

Sarcode.—A term applied by Dujardin to the protoplasm of cells.

Sarment. — A long, slender stolon or branch.

Sarmentose, Sarmentous, or Sarmentaceous.—Bearing sarments.

Scabrous.—Rough or harsh to the touch. Applied to leaves, etc.

Scalariform. — Ladder-like. Applied to ducts or tracheids whose markings resemble the rounds and spaces of a ladder.

Scandent.—Climbing. Applied to stems that climb by means of organs modified for the purpose.

Scape.—A naked, or nearly naked, flowering stem that springs from a root or rhizome.

Scapigerous.—Bearing scapes.

Scarious.—Dry, membranous. Applied to parts of flowers, etc.

Schizocarp.—A pericarp that dehisces into two or more one-seeded indehiscent mericarps.

Scion.—A twig or young shoot.

Sclerenchyma. — Hard bast, or bast-fibers. Used by some in a more extended sense, to include all sorts of lignified fibrous cells or cell derivatives.

Sclerogen.—A name for the hard matter deposited in sclerotic or stone cells.

Sclerotium.—A compact mass of hyphæ filled with nourishment and constituting a dormant or resting-stage in the development of some fungi.

Scorpioid.—Curved like the tail of a scorpion. Applied to certain cymes like those of the Forget-me-not and Heliotrope.

Scrobiculate.—Possessing minute or shallow depressions.

Scutate.—Shaped like a buckler.

Scutellum.—A shield-shaped expansion of the hypocotyl in grasses, which serves to absorb nutriment from the endosperm.

Secund.—Applies to flowers or other organs that are arranged along one side of a lengthened axis.

Secundine.—The inner coat of the ovule.

Semi-anatropous.—The same as amphitropous.

Semi-terete.—Half-cylindrical. Applied to some petioles, stems and leaves.

Seminal.—Belonging to the seed.

Sepal.—One of the leaves of the outer whorl of floral organs.

Sepaloid.—Like a sepal.

Septate.—Possessing septa or partitions.

Septicidal.—Applied to that form of capsular dehiscence in which the opening takes place along the line of junction of the carpels.

Septifragal.—Applied to that form of capsular dehiscence in which the opening takes place lengthwise along the middle of each carpel.

Septum.—A partition, as the membrane or wall which separates adjacent loculi in an ovary.

Sericeous.—With a pubesence of very fine, appressed, silky hairs.

Serrate.—Toothed with sharp teeth projecting forward like the teeth of a handsaw.

Serrulate.—Serrate with minute teeth.

Sessile.—Not stalked; inserted directly on the axis, as when a leaf-blade is attached directly to a stem.

Seta.—A bristle. The stalk of the capsule in Mosses.

Setaceous.—Bristle-shaped.

Setiform.—Bristle-like in shape.

Setigerous, or Setiferous. — Bearing bristles or stiff hairs.

Sheath.—Applied to the bases of leaves like those of grasses, that ensheath the stem. See also Medullary Sheath.

Sieve Tissue.—A cellular tissue made up of thin-walled cells which possess areas with sieve-like markings. The tissue is characteristic of the phlöem.

Sigillate.—Marked as if with a seal.

Silicle.—A short and broad silique.

Silique.—The slender, two-valved capsule of some Cruciferæ. It is divided into cells by a false partition stretched between two opposite parietal placentæ, and which often persists after the valves have fallen away.

Sinuate.—Wavy; winding in and out. Applied to the margins of leaves and other flattened organs.

Soboliferous.—Bearing vigorous shoots.

Soredium.—One or more algal cells wrapt in hyphæ and discharged from the fronds of Lichens, serving the purposes of vegetative propagation.

Sorosis.—A fruit like that of the Mulberry, which consists of a collection of small fleshy fruits, the product of a compact flower-cluster.

Sorus.—The name applied to the fruit dot or collection of sporangia of the Ferns.

Spadix.—A fleshy spike, commonly enveloped in a spathe.

Spathaceous, or Spadiceous.—Furnished with a spathe, or resembling a spathe.

Spathe.—A peculiar bract, often large and colored, which subtends or envelops a spadix.

Spatulate.—Resembling an old-fashioned spatula in outline. Applied to leaves and other flattened organs.

Spermatium.—A non motile male gamete, such as those produced by the red marine Algæ.

Spermatozoid.—The same as Antherozoid.

Spermoderm.—The same as Episperm; the outer covering of the seed.

Spermaphore.—The same as placenta.

Spermogonium. — A receptacle in which spermatia are developed.

Sphaeraphides. — Clusters of needle-shaped crystals arranged in spherical masses. The term is extended to include other crystalline masses having a somewhat rounded shape.

Spike.—That form of indeterminate anthotaxy in which the flowers are sessile, or nearly so, and arranged on a lengthened axis.

Spicate.—Disposed in spikes.

Spine.—A thorn; either a sharpened, hard and usually leafless branch, or a leaf or a part of one that has a sharpened and rigid form.

Spinose, or Spinous.—Possessing thorns; or shaped like a thorn.

Spiral Duct.—A duct whose wall has a spiral thickening on its interior surface.

Spongiole.—A name formerly applied to the spongy tissue of the root-tip, on account of its supposed property of sucking up moisture like a sponge.

Sporangiophore.—The modified leaves in the Equisetineæ which produce sporangia on their inner surface.

Sporangium.—A spore-case enclosing asexual spores.

Spore.—The term applied to the free reproductive cells of cryptogams. They may be sexual or asexual, motile or non-motile. A spore produced by the conjugation of two like cells is called a *zygospore;* the sexual spores produced in oögonia are called *oospores;* and those produced in carpogonia, *carpospores*. Spores endowed with locomotive powers are often called *zoospores* and *swarm-spores*. The smaller of the two kinds of spores produced by the Selaginellas and Quillworts are called *microspores*, and the larger, *macrospores*.

Sporidium.—A spore produced on a promycelium.

Sporiferous.—Spore-bearing.

Sporogenous.—Spore-producing.

Sporocarp.—A term applied to the matured product of the fertilization of the carpogonium.

Sporogonium.—A name applied to the sporocarp of the Mosses.

Sporophore.—The part of a sporogonium that bears the spores. The plant which in Bryophyta and Pteridophyta bears the asexual spores, is also called the sporophore. It is more properly called the sporophyte.

Sporophyte.—See Sporophore.

Sporule. — A term applied to a minute spore; also sometimes to minute granules within a spore.

Squamate.—Scaly.

Squamiform.—Scale-like.

Squarrose. —Applied to stems or other organs that are roughened with closely arranged bracts or other spreading processes.

Stamen.—The pollen-bearing organ of the flower, when complete, consisting of a stalk or filament and a pollen-sac or anther.

Staminate.—Possessing stamens. Applied to flowers which have stamens but not pistils.

Stameniferous.—Bearing stamens.

Staminode.—A stamen-like organ; a rudimentary or imperfectly developed stamen.

Stellate.—Star-shaped, or with parts radiating from a centre, as stellate stigmas, stellate hairs, etc.

Stereom.—That part of a fibro-vascular bundle whose main function is to impart strength to it.

Sterigma (*pl.* Sterigmata). — A stalk from which a spore or a spermatium is separated by abjunction.

Sterile.—Unproductive. A sterile flower is one which does not possess a pistil, or that cannot produce seed.

Stigma.—That portion of the pistil which receives the pollen.

Stigmatic.—Belonging to the stigma.

Stipe, or Stipes.—The stalk of a Fern leaf; also applied to the stalk possessed by some pistils. In Fungi, the stalk which bears the pileus.

Stipitate.—Possessing a stipe.

Stipular.—Belonging to stipules.

Stipulate.—Possessing stipules.

Stipule.—One of the blade-like bodies at the base of the petioles of leaves.

Stolon.—A branch which bends over and strikes root.

Stoloniferous.—Stolon-bearing.

Stoma (*pl.* Stomata).—A breathing-pore, or opening found in the epidermis of the higher plants. Stomata are usually most abundant on the under surface of leaves.

Stone-fruit.—The same as drupe, q. v.

Stramineous. — Straw-colored or straw-like.

Striate.—With fine longitudinal lines.

Strict.—Upright; straight.

Strigose, or Strigous. — Armed with sharp and stout appressed hairs.

Strobile.—A multiple fruit in which the seeds are enclosed by prominent scales, as a Pine cone.

Stroma.—A body composed of compactly arranged hyphæ, on which sporocarps are borne.

Strophiole.—The same as caruncle, q. v.

Struma.—A wen-like appendage or swelling.

Strumose, or Strumous. — Swollen on one side; possessing a wen-like protuberance

Style.—That portion of the pistil which connects the ovary with the stigma.

Stylopodium. — A disc-like enlargement occurring at the base of the style in some flowers.

Suberin.—Cork-substance, a modification of cellulose; the same as cutin, q. v.

Suberous.—Corky; belonging to cork.

Submerged.—Applied to organs that grow immersed in water, as submerged leaves, etc.

Subulate.—Awl-shaped.

Succulent.—Thickened and juicy.

Sucker. — An ascending or erect branch from a creeping, underground stem.

Suffrutescent.—Applied to a stem which is slightly shrubby at the base only.

Suffruticose.—Applied to an under-shrub, or low shrub.

Sulcate.—Having furrows or grooves.

Surculose.—Bearing suckers.

Surculus.—A sucker.

Superior.—Applied to an ovary that is not at all adherent to the calyx. Also applied to a calyx whose tube closely adheres to the ovary, so that its limb, or spreading portion, appears to spring from the top of the latter.

Supervolute.—That form of æstivation in which the gamophyllous calyx or corolla is both plicate and twisted, as in the corollas of Stramonium and Morning-glory.

Suspended.—A term descriptive of the position of the ovule when it hangs perpendicularly from the top of the ovary wall.

Suspensor.—A term applied to the chain of cells formed by division of the germ-cell in the embryo-sac previous to the formation of the embryo. See Pro-embryo.

Suture.—A seam. Applied to the seams of a pod or capsule. That suture is called the *ventral* which corresponds to the line of junction of the edges of the carpel or of adjacent carpels; and that is called the *dorsal* which corresponds to the midrib of the carpel.

Swarm-spore.—A spore moving by means of cilia.

Syconium.—The peculiar multiple fruit of the Fig, which consists of a fleshy, hollow receptacle containing numerous achenium-like fruits.

Symmetrical.—Applied to flowers whose whorls regularly alternate with each other and agree in numerical plan.

Sympetalous.—The same as gamopetalous.

Symphysis.—A coalescence or union of parts

Sympetalous.—The same as gamopetalous.

Synantherous.—The same as syngenesious. Stamens coalescent by their anthers.

Synanthesis.—The simultaneous maturing of stamens and pistils in the flower.

Syncarp.—A multiple fruit.

Syncarpous.—Applied to pistils and fruits when they are made up of two or more united carpels.

Syncotyledonous.—With coalescent cotyledons.

Synergidæ.—A term applied to the two cells of the egg-apparatus that are associated with the germ-cell in the embryo-sac.

Syngenesious.—A term applied to stamens which are united by their anthers.

Synsepalous.—The same as gamosepalous.

Tapetum.—A term applied to the lining membrane of the pollen-sac.

Tap-root.—The main root, or downward continuation of the plant axis.

Taxonomy.—That portion of a science which treats of classification and nomenclature.

Tegmen.—The inner seed coat. (See Endopleura.)

Teleutospore.—A peculiar kind of spore produced by the Uredineæ or Rusts late in the season.

Tendril.—A leaf, a portion of a leaf, or a branch so modified as to serve the purpose of a climbing organ.

Teratology.—The science of monstrosities or malformations.

Terete.—Nearly cylindrical. A term descriptive of certain stems, leaves, pistils, etc.

Terminal.—Placed at the end, as terminal buds.

Ternate.—Applied to radiately compound leaves that have three leaflets.

Testa.—The outer coat or covering of the seed.

Tetradynamous.—Applied to stamens when there are six in the flower, four of them longer than the other two.

Tetracarpellary.—Having four carpels.

Tetracyclic.—Applied to a flower possessing four whorls of floral organs.

Tetramerous.—Applied to flowers constructed on the numerical plan of four.

Tetrandous.—Possessing four stamens.

Tetrapetalous.—Possessing four petals.

Tetrasepalous.—Possessing four sepals.

Tetrarch.—A term descriptive of radial fibro-vascular bundles having four rays.

Tetraspore.—Applied to one of the asexual spores of the Red Marine Algæ, the spores usually occurring in groups of four.

Tetrastichous.—In four perpendicular rows. Applied to phyllotaxy.

Thalamiflorous.—With the parts of the flower inserted on the receptacle or hypogynous.

Thalamus.—The receptacle or torus.

Thallus.—Applied to a plant body in which there is no differentiation into root, stem and leaves.

Theca.—A capsule, a spore-case, or an anther-cell.

Thermotropism.—That property possessed by some organs of bending toward or away from a source of heat.

Thorn.—The same as spine.

Thyrse, or Thyrsus.—A compact panicle, like the inflorescence of the Grape.

Tissue.—A collection of cells of a similar character.

Tomentose, or Tomentous.—Applied to surfaces which are covered with matted hairs.

Torose. — Cylindrical, with constrictions and enlargements at intervals.

Tortuous.—Irregularly bent or twisted.

Torus.—Another name for receptacle, q. v.

Trabeculate.—Having bars running crosswise.

Tracheæ. — Rows of cells which become confluent by losing their intervening partitions; vessels or ducts.

Tracheary - tissue. — A term which includes both tracheids and tracheæ or ducts.

Tracheid—An elongated cell whose markings resemble those of ducts. It differs from a duct in the fact that it represents a single cell, while a duct represents two or more cells that have become confluent, end to end.

Trabecular Duct.—A duct whose cavity or lumen is crossed by ligneous threads or bands.

Trachycarpous.—Having the fruit roughened.

Trachyspermous.—Having the seed roughened.

Transpiration.—The evaporation of water or other vaporizable matter from the plant.

Triadelhous.—Applied to stamens that are united by their filaments into three sets.

Triandrous.—Having three stamens.

Trianthous.—Three-flowered.

Triarch. — A term descriptive of radial fibro-vascular bundles having three rays.

Tricarpellary.—Consisting of three carpels.

Tricarpous.—Haxing three carpels or three fruits.

Trichoblast.—An internal hair, like those which project into the intercellular spaces of the stems of some Water-lilies.

Trichocarpous.—Having the fruit covered with hairs.

Trichogyne. —A style-like appendage to the carpogonia of certain Carpophyta.

Trichome.—A general term for a plant-hair or any of its various modifications.

Trichotomous.—Branched into three equal branches.

Tricoccous.—Having three cocci, or mericarps.

Tricuspidate.—Tipped with three cusps or small hard teeth.

Tridentate.—Three-toothed.

Trifoliate.—Possessing three leaves.

Trifoliolate. — Applied to a compound leaf that has three leaflets.

Trigonous.—Three-angled.

Trigynous.—Having three pistils.

Trijugate.— Having three pairs of leaflets.

Tri-lobate.—Three-lobed.

Tri-loculate.—Having three loculi.

Trimerous.—Applied to flowers constructed on the numerical plan of three.

Tri-morphism.—A term used to indicate the fact that hermaphrodite flowers of three different kinds, short-styled, mid-styled, and long-styled, are produced on the same species of plant.

Tripartite.—Three-parted.

Tri-petalous.—Three-petaled.

Tri-phyllous.—Three-leaved.

Tri-pinnate.—Three times pinnately-compounded.

Triquetrous. —Three-angled, or triangular-prismatic. Applied to certain stems and leaves.

Tri-sepalous.—Three-sepaled.

Tristichous.—Arranged in three perpendicular rows. Applied to phyllotaxy.

Tri-stylous.—Three-styled.

Tri-sulcate.—Three-grooved.

Tri-ternate. — Applied to a leaf that is thrice compounded on the ternate plan.

Trochlear.—Pulley-shaped.

Truncate.—Ending abruptly, as if cut off.

Tryma.—A drupe-like fruit, which is commonly two-celled, has a bony nucleus and thickish but fibrous epicarp. Example: a hickory-nut.

Tuber.—A thickened portion of an underground stem.

Tuberculate, or Tubercled. — Warty; bearing tubercles.

Tuberiferous.—Bearing tubers.

Tuberous.—Tuber-like, or tuber-bearing.

Tubuliflorus. — Having the heads composed of tubular flowers.

Tubular.—Nearly cylindrical and hollow like a tube, as a tubular corolla or calyx.

Tunicate.—Having coverings or coats. A bulb like that of the Onion is tunicated.

Turbinate.—Top-shaped.

Turgescence.—The distension of the cells of plants with sap, producing rigidity or firmness of the tissue.

Twining-plant.—A plant that climbs by twisting around a support.

Tylosis.—A protuberance of the wall of a cell through the pit in the wall of an adjacent duct.

Uliginose. — Growing in swampy places.

Umbel.—That form of indeterminate inflorescence in which the axis is very short and the pedicels radiate from it like the rays of an umbrella.

Umbellet, or Umbellule.—One of the secondary umbels of a compound umbel.

Umbellate.—Bearing umbels.

Umbilicate. — With a depression resembling that of the navel.

Umbraculiform. — Shaped like an umbrella.

Uncate, or uncinate.—Bent into the form of a hook.

Undate.—(See Undulate).

Undulate.—Wavy; having a margin that flows gently in and out. Applied to leaves and other flattened organs.

Unguis.—A claw.

Unguiculate.—Clawed. Applied to petals that have stalks or claws.

Uniaxial.—A stem or root is uniaxial when it does not branch.

Unicellular. — One-celled. Applied to plants that consist of a single cell.

Uniflorate.—One-flowered.

Unifoliate.—One-leaved.

Unifoliolate. — Applied to a compound leaf that has but one leaflet, as the leaves of the Orange and Lemon.

Unijugate.—Consisting of one pair.

Unilateral.—One-sided.

Unilocular.—Possessing one loculus.

Unipetalous.—One-petaled.

Uniserial.—Arranged in one series. Applied to parts that are arranged in one horizontal whorl.

Unisexual.—Possessing but one sex.

Urceolate. — Urn-shaped. Applied to a gamophyllus calyx or corolla that is shaped somewhat like an urn.

Uredospore.—One of the spores produced early in the season by the Uredineæ or Rusts, and which form rust-like spots on grasses and other plants.

Utricle —Literally, a little bladder. The name applied to a one-seeded dry fruit with a bladdery, loose pericarp, which either does not dehisce or dehisces irregularly.

Vacuole. — A sap-cavity in the protoplasm of a cell.

Vaginate.—Sheathed.

Variolate. — With spots or markings, reminding one of the pits of small-pox.

Valvate. — Possessing valves, or opening by valves, as in the dehiscence of some anthers. Also applied to that form of æstivation in which the pieces of the whorl barely touch each other by their edges, but do not overlap.

Vascular. — Possessing vessels or ducts. The Pteridophyta are often called *Vascular Cryptogams.*

Vasiform.—Having the form of a vessel.

Vasiform Elements.—A general term including tracheids and ducts.

Vein.—One of the fibro-vascular bundles of a leaf.

Veinlet.—A small vein.

Venation.—The veining or system of veins, as that of a leaf.

Ventral.—Pertaining to the front surface. The ventral aspect of a leaf is that which is usually uppermost or presented to the strongest light; or, in the case of a carpellary leaf, the inner or ovule-bearing surface.

Ventricose.—Swollen on one side.

Vermicular.—Worm-shaped.

Vernation. — The same as prefoliation. The arrangement of the leaves in the bud.

Verrucose.—Warty; covered with protuberances.

Versatile.—Applied to the anther when inserted on the slender apex of the filament, in such a manner as to turn readily as on a pivot.

Verticil.—A whorl, or circle of leaves, all in the same horizontal plane.

Verticillaster.—A term applied to the pairs of opposite cymes that occur in the axils of the leaves of Mints and at first sight resemble whorls.

Verticillate. — Whorled; arranged in whorls.

Vesicle. — A diminutive air-vessel or bladder.

Vespertine. — Belonging to the evening. Applied to flowers that open at nightfall.

Vexillary.—Applied to that form of imbricate æstivation observed in the corolla of the Pea, in which the other petals are enwrapped by the vexillum.

Vexillum.—The upper and largest of the five petals of a papilionaceous flower.

Villous, or Villose.—Covered with long, soft, shaggy hairs.

Violaceous.—Violet-colored.

Virgate. — Straight and slender, like a wand.

Vittæ.—The stripes on the fruits of the Umbelliferæ.

Vittate.—Possessing vittæ.

Voluble.—Twining.

Velum partiale. — A membrane or veil which in some of the Hymenomycetes stretches from the margin of the pileus to the stipe

Velum universale. —A membrane which in some of the Hymenomycetes covers the entire sporocarp.

Volva.—A covering possessed by the fruiting organs of some fungi. The same as velum universale.

WATER-PORES. — Organs resembling stomata, but discharging water instead of gaseous matter, which occur on some leaves.

Whorl.—Organs disposed in a circle about a central axis are said to be arranged in a whorl.

Wood-cells. — Libriform cells and other elongated, taper-pointed cells, not distinctly marked with pits, spiral or annular markings, found in the wood of plants.

Wood-parenchyma.—Elongated parenchyma cells associated with wood-cells.

XANTHOPHYLL. — A yellow coloring matter observed in autumn leaves.

Xerophilous. — A term applied to plants which, like the Cactuses, are adapted to dry regions.

Xylem.—That portion of the fibro-vascular bundle which contains ducts or tracheids.

ZOÖGAMETE.—A gamete or sexual spore endowed with the power of locomotion.

Zoögonidium.—A motile gonidium.

Zoösporangium. — A sporangium which produces motile spores.

Zoöspore.—Literally, an animal spore. A vegetable spore endowed with the power of locomotion, and therefore appearing like an animal.

Zygomorphous.—Flowers which are divisible in only one plane into similar halves are called zygomorphous.

Zygospore.—A reproductive spore formed by the union of the protoplasm of two like cells.

Zygote.—A term for the product of the union of any two reproductive cells or gametes.

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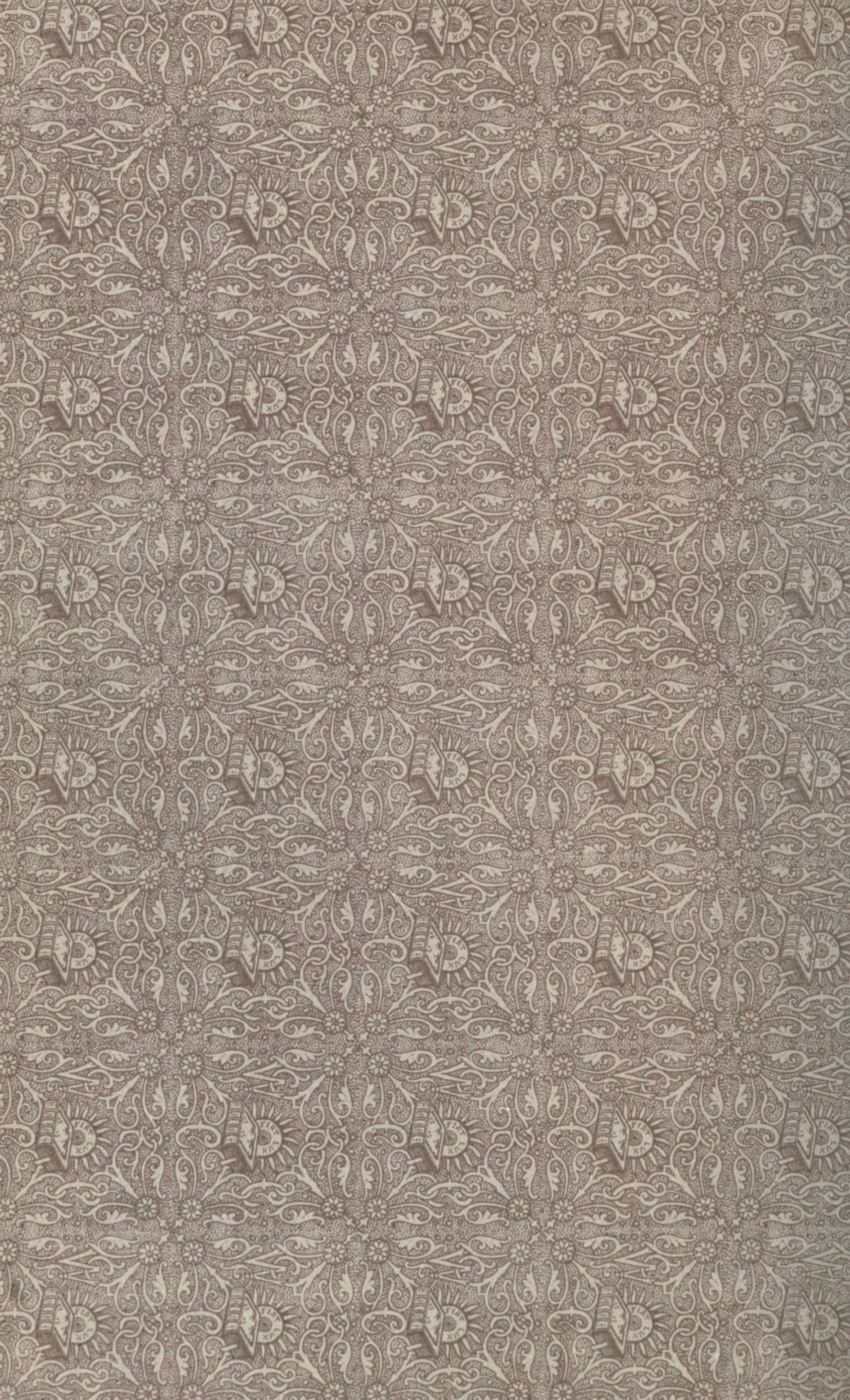
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